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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN

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PART II.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. I., 1928.]

ART. I.—*Notes on New Zealand Hydroida.*

By R. E. TREBILCOCK.

(With Plates I.-VII.)

[Read 8th March, 1928: issued separately 27th September, 1928]

During a visit to New Zealand in April and May, 1923, I spent a few days collecting Hydroids at Auckland, Island Bay (Wellington), New Brighton (Christchurch), St. Clair (Dunedin), and Bluff. The collecting was done solely in rock pools at low tide, and among algae washed ashore, but it resulted in several new species, a number of species not hitherto recorded from New Zealand, and numerous other and interesting forms.

The present paper deals with this collection, and also includes references to a few specimens collected by my late colleague, Mr. J. F. Mulder, from Stewart Island "oyster" shells many years ago, and to some specimens kindly sent to me by Mr. W. M. Bale, F.R.M.S., for examination and comparison.

I have to thank Mr. W. M. Bale for the very great assistance he has rendered me by identifying species in respect of which I had doubts, by sending me literature and specimens from his own extensive collection for examination, and by valuable advice throughout the preparation of this paper.

Fam. CLAVIDAE.

ENDOCRYPTA HUNTSMANI (Fraser).

Crypta huntsmani Fraser, 1911, p. 19.

Endocrypta huntsmani Fraser, 1912, p. 216; 1913, p. 149; 1914, p. 109.

Ascidioclava parasitica Kirk, 1915, p. 146.

I have compared a specimen of *Ascidioclava parasitica* from New Zealand (kindly sent to me for examination by Mr. Bale) with specimens of *Endocrypta huntsmani* from Departure Bay, west coast of Canada (received from Dr. C. McLean Fraser), and there is not the slightest doubt that not only do they belong to the same genus, but also that they are not specifically distinct.

Mr. Bale's specimen is from the peripharyngeal groove of a *Polycarpa,* and was collected at Wellington, N.Z.

Fam. PENNARIIDAE.

PENNARIA AUSTRALIS Bale.

Numerous specimens, growing in a shallow rock-pool at the entrance to Auckland Harbour.

This species has not hitherto been recorded from New Zealand.

INCERTAE SEDIS.

Saaba (?) scandens, n. sp.

(Plate I., Figs. 1, 1*a*.)

Specimens from Island Bay no doubt belong to the same genus as *Saaba arenosa* (Bale).

The hydrocaulus is fascicled in its proximal part, unjointed, and consists of string-like stems, with a few ascending branches. The perisarc has a tough and cartilaginous appearance. The polyp-tubes are few, and spring irregularly from all sides. Near the end of the polyp-tubes there is an annular thickening, and often another just below it, probably due to regeneration. Beyond the distal thickening the edge of the polyp-tube is sometimes quite sharp, sometimes rather ragged. Inside the annular thickening is often a narrow septum. Unfortunately no hydranths are present.

Unlike Bale's species, the present form is climbing in habit, the hydrocaulus adhering loosely to other hydroids.

The height of the largest specimen, which is incomplete, is about 35 mm.

Springing from several of the polyp-tubes are large sac-like bodies, which are possibly gonangia. As in *Saaba arenosa* they are formed of very thin colourless perisarc which does not stain readily, and have the whole exterior surface coated with closely adhering grains of sand, calcareous particles and Foraminifera.

In the absence of hydranths the position of this genus is very uncertain, and it can only provisionally be referred to the Hydroida.

Fam. CAMPANULARIIDAE.

Obelia geniculata (Linn.).

Loc.—Island Bay, and New Brighton (Christchurch).

Obelia australis v. Lendenfeld.

I found this species, with numerous gonothecae, growing in tide-pools below the swimming pool at St. Clair (Dunedin).

Orthopyxis formosa, n. sp.

(Plate I., Figs. 2-2*e*.)

Hydrorhiza broad, flattened, with flanged margin, forming an irregular network.

Hydrosoma varying from 1·2 mm. to 2·3 mm. in height.

Peduncles somewhat flattened, usually strongly and spirally undulated; a single spherule below each hydrotheca.

Hydrothecae large, compressed; in broad aspect with wide base and only slightly expanding upwards, and with thickening of

walls mostly extending from the base up to just below the rim, where there is an additional thickening on the outside forming a stout band which completely surrounds the upper part of the hydrotheca; in narrow aspect narrower at the base and with little thickening except at the base and near the rim.

Margin rising slightly above the thickened rim, very thin, furnished with about 12 rounded teeth.

Gonothecae not present.

Hab.—At entrance to Auckland Harbour, on floating seaweed.

Occasionally hydrothecae are found without any thickening, but such have the walls more or less wrinkled, and are obviously abnormal. The hydrothecae vary considerably in size, as may be seen by reference to my figures which are all drawn to the same scale.

ORTHOPYXIS DELICATA, n. sp.

(Plate II., Figs. 1-1*f*.)

Hydrorhiza broad, only slightly flattened, with a slightly flanged margin.

Hydrosoma varying from 0·75 mm. to 1·5 mm. in height; peduncles somewhat flattened, strongly and spirally undulated throughout their entire length; a single spherule below each hydrotheca.

Hydrothecae large, slightly compressed; in broad aspect with a wide base, but expanding considerably upwards; in narrow aspect narrow at the base and expanding still more upwards so as to make the aperture more nearly circular; walls in broad aspect thickened near the base and becoming only slightly thinner towards the rim, in narrow aspect much thinner throughout; no annular thickening around the rim.

Margin of hydrothecae rather thin, furnished with from about 10 to 15 rounded teeth.

Gonothecae about 1·2 mm. in length, springing from short expanding peduncles, somewhat pear-shaped, more rotund on one side than the other, thus making them curved, with a large, circular, terminal opening.

Loc.—St. Clair (Dunedin), growing over the surface of delicate algae and polyzoa. In the latter case the hydrorhiza forms an anastomosing network roughly corresponding with the cells of the polyzoa.

The hydrothecae vary considerably in size, as will be seen by reference to my figures, which are all drawn to the same scale.

ORTHOPYXIS CRENATA (Hartlaub).

Numerous specimens with gonothecae, from Island Bay.

SILICULARIA BILABIATA (Coughtrey).

I found this species growing profusely over *Laminaria* washed ashore at Island Bay.

Silicularia campanularia (v. Lend.).

I found this species in large numbers at St. Clair (Dunedin) and Bluff.

Fam. LAFOEIDAE.

Hebella calcarata (L. Agassiz).

I found numerous examples of this widely spread species growing over *Sertularella subarticulata* from Stewart Island.

Hebella corrugata (Thornely).

I found specimens of this widely spread species growing on *Thecocarpus formosus* var. *inarmatus*, n. var., at Island Bay.

In my specimens the aperture of the hydrothecae is not as oblique as figured by most authors.

Measurements.—Length of pedicel 0·20—0·45 mm.; length of hydrotheca 0·72—0·90 mm.; diameter of hydrotheca 0·37—0·55 mm.

Not previously recorded from New Zealand.

Filellum serratum (Clarke).

Specimens of this species occur on several other hydroids from Bluff, Stewart Island, and Island Bay. Not previously recorded from New Zealand.

Perisiphonia quadriseriata, n. sp.

(Plate II., Figs. 2-2*d*.)

Hydrorhiza consisting of a dense mass of tubes forming a parchment-like disc.

Hydrocaulus stout, straight, attaining a height of 14 cm., fascicled, consisting of a single axial tube, bearing hydrothecae, surrounded by a large number of peripheral tubes bearing sarcothecae only.

Hydrocladia sub-opposite, forming an angle of about 60° with the hydrocaulus, attaining a length of about 22 mm., stout, flattened, oval in section, about 0·5 mm. in broader (vertical) diameter, and about 0·4 mm. in narrower; fascicled, consisting of a single axial tube bearing hydrothecae, surrounded by a large number of peripheral tubes, none of which spring from the axial tubes of the hydrocladia; hydrocladia not of smaller diameter at base than elsewhere.

Hydrothecae borne on axial tubes of hydrocaulus and hydrocladia, close-set, each usually overlapping the proximal portion of its successor in the same series, cylindrical, with a slightly bulging profile, lying closely adpressed to the axial tube for a considerable part of their length, the terminal portion curving away from the axial tube and projecting for a short distance (about 0·1 mm. in the longest example) through the fascicle of peripheral tubes. Aperture of hydrothecae circular, margin smooth.

Base of hydrothecae passing into a projection of the axial tube corresponding to a hydrothecal peduncle, and containing a strong diaphragm which slants from the outside inwards and slightly downwards.

Hydrothecae on hydrocaulus in two series on opposite sides of the peripheral tube, both series lying in the same plane, alternate though not always regularly spaced, varying in length with the thickness of the mass of peripheral tubes through which they project.

Hydrothecae on the hydrocladia in four series, two series close together on the abcauline side, and two series close together on the adcauline side, the two abcauline series being widely separated from the two adcauline. Hydrothecae, in each series, regularly alternating with those of adjacent series on both sides of it, but opposite to those of the series diagonally opposite.

Sarcothecae numerous, scattered on hydrorhiza, hydrocaulus and hydrocladia, short, cylindrical, diameter wide compared with their length, borne on slight projections from the peripheral tubes, and separated from the projections by a constriction.

Gonosome, not present.

Locality.—Island Bay, washed ashore.

The hydrocladia would appear from casual examination to be opposite, but, on dissecting away the mass of the peripheral tubes, it is found that the axial tubes of the hydrocladia spring from the axial tube of the hydrocaulus at points that would otherwise be occupied by alternate hydrothecae. The hydrocladia are thus sub-opposite.

The peripheral tubes communicate freely with each other, and with the axial tube of the hydrocaulus by numerous circular or oval apertures. They do not however directly communicate with the axial tubes of the hydrocladia except by one or two apertures near the base of each hydrocladium and within the bundle of peripheral tubes of the hydrocaulus.

The axial tubes of the hydrocladia are not thickened to any great extent, but that of the hydrocaulus has a massive wall, built up of numerous layers.

In the axil of each hydrocladium is a hydrotheca which differs from the others. It springs from the hydrocladium immediately above the point of origin of the latter, but lies within the peripheral tubes of the hydrocaulus through which it projects. It curves in the same direction as the hydrothecae of the hydrocaulus, and in the opposite direction to the other hydrothecae on the adcauline side of the hydrocladium. Perhaps it would be more correct to say that the axial tube of the hydrocladium springs from the base of this hydrotheca, for the latter certainly belongs more to the hydrocaulus than to the hydrocladium. The wall of the lower part of this axial hydrotheca is much thickened, and from an aperture just below the diaphragm springs a peripheral tube. This tube immediately divides, one branch running up the hydrocaulus and the other along the hydrocladium.

Other peripheral tubes running up the hydrocaulus from below also divide near the point of origin of the hydrocladium, one branch continuing upwards and the other going along the hydrocladium.

The proximal hydrotheca on each hydrocladium on the abcauline side is separated from the others by a short distance, the first hydrotheca of the adjoining series being missing.

The present species is represented in my collection by a single specimen.

Fam. HALECIIDAE.

Halecium flexile Allman.

I found a few small colonies of this species growing in a rock pool at St. Clair (Dunedin), also at Bluff.

Halecium lenticulare, n. sp.

(Plate III., Figs. 3-3*d*; Plate IV., Figs. 1-1*b*.)

Colonies small, attaining a height of a little more than 1 cm., not fascicled, regularly and markedly sympodial (an example of cincinnal monopodia), the stems usually having a marked zig-zag appearance, sparingly bipinnate.

Primary hydrothecae low. Secondary hydrothecae with a large basal cavity, somewhat symmetrically developed. Hydrothecae usually with very thin walls, open margin curved outwards and usually everted, particularly on the adcauline side. Diaphragm well developed, but extremely thin; aperture narrow, often terminating in a very delicate membranous tube, which stretches a considerable distance into the basal cavity. Below the diaphragm a well developed adcauline thickening of the wall ("pseudo-diaphragm") often extending completely round the hydrotheca but always thicker on the adcauline side. Sometimes another thickening, similar, but not so pronounced, near the base of the basal cavity.

Regenerations of hydrothecae markedly active, unregenerated examples being an exception to the general rule.

Gonothecae borne on the apophyse immediately below the primary hydrothecae. Male gonothecae borne mainly on the distal parts of the colony, small, ovate, much flattened. Female gonothecae usually confined to the proximal parts of the colony, large, lenticular, with a circular opening in the distal part of the abcauline side; margin of opening thickened.

Localities.—St. Clair (Dunedin), Bluff, Island Bay (Wellington).

The type specimen is from Bluff Harbour.

The specimens from St. Clair differ from the type in that most of the perisarc is enormously strengthened by internal annular thickenings, arranged more or less diagonally around stem and branches.

The specimens from Island Bay resemble those from St. Clair in the above respect, but differ from those from the other two localities. In the latter the hydrothecae, primary and secondary, are usually almost, if not quite, in a straight line with the internode from the apophyse of which they spring, thus giving the colony a distinct zig-zag appearance. In the Island Bay specimens, however, the apophyse and hydrothecae curve away from the line of the internode, and the succeeding internode is in a straight line with its predecessor, the whole stem thus being straight. (Pl. IV., Fig. 1.) Specimens from all three localities bear gonothecae.

HALECIUM CORRUGATISSIMUM, n. sp.

(Plate III., Figs. 1-1*f*.)

Colonies small, attaining a height of about 5 cm. Stem not fascicled, strongly annulated, and divided into very short internodes. Growth irregularly sympodial, the main axis not being produced beyond the primary hydrotheca, immediately below the diaphragm of which spring one, two or three branches, the branching thus being sometimes falsely dichotomous or falsely trichotomous.

The branches do not lie in one plane, but are quite irregular in this respect.

Pedicels expanding upwards, much and deeply corrugated. Hydrothecae large, margins broadly expanded and slightly everted, with a well marked row of dots. Margins or the whole hydrotheca sometimes reduplicated.

Diaphragm fairly well developed, but thin; aperture wide.

Gonothecae borne on short pedicels below the hydrothecae, mainly on the upper part of the colony, ovoid, with from 5 to 7 deep and even annulations; upper part usually devoid of annulations, and more or less hemispherical.

Locality.—St. Clair (Dunedin).

The young hydranth is enclosed by an almost spherical, thin, chitinous ball, which eventually splits away from the hydrophore. Fig. 1*d* shows an example with the splitting process just commenced.

This species is closely allied to *H. speciosum* Nutting (1901, p. 181, pl. xxii., figs. 1, 2).

HALECIUM EXPANSUM, n. sp.

(Plate III., Figs. 2-2*c*; Plate IV., Figs 2-2*b*.)

Colonies small, attaining a height of about 6 mm., main stem either not fascicled or sometimes strengthened by one or two irregular peripheral tubes, irregularly sympodial, the prolongation of the axis often developing quite as strongly as the branch, false dichotomy occasionally met with.

Primary hydrothecae sessile. Secondary hydrothecae with a large basal cavity. Hydrothecae wide, shallow and expanding,

with very thick walls, margin never curved outwards. Diaphragm well developed and massive, aperture large. Walls of basal cavity without any marked thickening. Between each hydrotheca and the basal cavity of the hydrotheca above it, a more or less spherical internode, the base of which springs from the inner edge of the diaphragm.

Regenerations of hydrothecae fairly active.

Gonothecae not present.

Locality.—Growing on roots of algae in rock-pools at St. Clair (Dunedin).

The branches are not confined to any particular plane, but are quite irregular in this respect. In the distal parts of some of the colonies the branching is very active, resulting in a bushy mass.

The ring of chitinous "dots" around the hydrothecae are not conspicuous; in fact, I could find them only in a few young hydrothecae that happened to be empty.

CAMPANULINA HUMILIS Bale.

(Plate IV., Figs. 3-3*d*.)

I found numerous specimens of the creeping form of this species growing on other hydroids, polyzoa, and the roots of algae, at St. Clair (Dunedin). After a long search among the material with a view to finding a gonosome, I discovered several branched specimens. These in their mode of branching agree with *Campanulina turrita* Hincks, except that the branching is more active and the hydrothecae consequently more crowded. My specimens are all small, the largest being only 1·35 mm. in height. The stems and branches are all closely annulated, or, sometimes, spirally constricted, throughout.

The specimens are in excellent state of preservation, with many of the polyps fully expanded. There is a web between the tentacles (see Fig. 3*c*), but it extends only a very short distance up.

Unfortunately, no gonothecae were present, so the assignment of the species to the genus *Campanulina* is provisional. Hitherto the species has been known by its creeping form only.

THYROSCYPHUS SIMPLEX (Lamouroux).

Specimens, with gonothecae, from Island Bay. The gonothecae are as described by Bale (1915), except that they are somewhat shorter and broader, their length being from 1·1 mm. to 1·2 mm., and their diameter at the widest part 0·7 mm.

Fam. LINEOLARIIDAE.

LINEOLARIA FLEXUOSA Bale.

There is a specimen of this small and little known species in the collection of the late Mr. Mulder. It has not hitherto been recorded from New Zealand.

Locality.—Stewart Island.

Fam. SYNTHECIIDAE.

Synthecium patulum (Busk.)

Billard (1925) has united *S. patulum* Busk and *S. orthogonium* Busk under the name *S. patulum*, concluding from his examination of specimens collected by the "Siboga" Expedition that the distinctions pointed out by Bale (1914), namely, the arrangement of hydrothecae, pinnae, and nodes on the hydrocaulus, cannot be relied on to separate the two specifically.

In the absence of gonothecae, I am assigning to this species specimens collected by me at Auckland Harbour and from Stewart Island.

They both differ from Billard's figures in that the orifice of the hydrothecae is very little, if at all, everted. Reduplication of the margin is not common. The measurements of the hydrothecae, however, generally agree with those given by Billard.

	Auckland Specimens.	Stewart Is. Specimens.
Length adnate - - - -	0·46—0·60 mm.	0·50—0·69 mm.
Length free - - - -	0·16—0·35 mm.	0·20—0·43 mm.
Diameter at mouth - - -	0·19—0·21 mm.	0·25—0·32 mm.
Interval between pairs of hydrothecae (measured from adnate part of one to the base of the next above it) - -	0·18—0·50 mm.	0·11—0·34 mm.

Fam. SERTULARIIDAE.

Selaginopsis monilifera (Hutton).

(Plate IV., Figs. 4, 4*a*.)

Bale (1915, p. 266) in his description of this species, under the name of *Selaginopsis dichotoma*, states that the hydrophyton is monosiphonic. All my New Zealand specimens are fascicled.

There is considerable variation in the distance between hydrothecae even in a single specimen; the space occupied by four hydrothecae in the four series (measured from the base of the first to the base of the fifth) varies in my specimens from 0·6 mm. to 1·45 mm. Occasionally, when widely separated, the hydrothecae lose their quadriserial arrangement and all lie in the same plane.

Localities.—St. Clair (Dunedin), Bluff, and Stewart Island.

This species has not hitherto been correctly figured.

Genus **Sertularella**.

Characters.—Hydrothecae with operculum of three or four valves; hydranths with abcaulinary caecum; hydrothecae alternate, opposite, verticillate, or spirally arranged.

The addition of the last three words to the above is rendered necessary by the discovery of *Sertularella irregularis*, n. sp.

One of the characteristics of the genus *Sertularella* is the presence of a more or less developed abcaulinary caecum, or blindsac. From the circumference of this, most markedly at the abcauline side, spring a number of threads a split external ectodermal lamella, according to Kühn which stretch to the wall of the hydrotheca, and hold the caecum in position. In many species, especially, curiously enough, in those in which the caecum is well developed, these threads have no definite points of attachment to the chitin, but appear to be attached only to the layer of ectoderm cells which is left adhering to the inside of the hydrotheca when the young hydranth shrinks away from it. This layer often breaks away, and lies loosely within the hydrotheca, but attached by the threads to the caecum.

In other species these threads have definite points of attachment to the chitin itself, the points of attachment being marked by a number of scars, or, sometimes, chitinous denticles which are usually minute. Occasionally, however, there is a comparatively large denticle at the abcauline side, and sometimes this is the only one that can be detected.

This line of denticles stretches obliquely backwards and downwards around the lower part of the hydrotheca. This line of attachment is the "apparent oblique septum" referred to by Bale (1914, p. 21) in his description of *S. divaricata.*

I have found that the angle at which this ring encircles the hydrotheca is fairly constant in each of the species I have examined, but often differs in closely allied species, and thus gives considerable assistance when in doubt as to which of two species a specimen belongs. For example, in *S. johnstoni* the highest point reached by the ring is about half way up the abcauline side of the hydrotheca; in *S. pygmaea,* which is so closely allied as to be considered by some authorities to belong to the same species, without doubt erroneously, the ring reaches to about one-third of the way up; while in *S. rentoni* it is quite close to the base, and only slightly diagonal.

SERTULARELLA PYGMAEA Bale.

Specimens, growing on other hydroids, from Bluff.

SERTULARELLA RENTONI Bartlett.

(Plate I., Fig. 3.)

I found this species growing in a rock-pool at St. Clair (Dunedin). No gonothecae were present. It has not hitherto been recorded from any other locality than Victoria.

In *S. pygmaea* the line of points of attachment of the caecum is less conspicuous than in *S. rentoni,* and at the front of the hydrotheca is usually much higher up, and runs around it in a more

diagonal position. This enables the two species to be separated with ease, even when no gonothecae are present.

Usually the walls of the hydrothecae are thin, but the margin is sometimes slightly thickened, but never to the extent found in the species next described.

Sertularella macrogona, n. sp.
(Plate I., Figs. 4-4*d*.)

Hydrocaulus attaining a height of about 1 cm., simple or irregularly branched, branches usually springing from inside a hydrotheca. Hydrocaulus and branches divided by slightly oblique joints into short internodes, each (with an occasional exception) bearing a hydrotheca.

Hydrothecae adnate for about one-third of their height, both series springing from the front, the two planes in which they lie being at about right angles to each other; hydrothecae tubular, smooth, slightly concave in outline on the abcauline side, the adcauline side being ventricose; the margin slightly thickened, especially at the adcauline side; aperture with three broad rounded marginal teeth, one superior, short and comparatively inconspicuous, and two lateral, much longer; no internal submarginal denticles. Operculum of three triangular pieces.

The hydrothecae lie at, approximately, an angle of 45° with the stem, and the aperture is, approximately, at an angle of 45° with the length of the hydrotheca, thus making the aperture at about right angles with the stem.

Gonothecae large, about 4 times as long and 2½ times as broad as the length of a hydrotheca, usually springing from inside hydrothecae, but sometimes borne on the front of the stem just below a hydrotheca, obovate, flattened and slightly depressed just above its widest part, and from the centre of the depression rises a narrow, converging tube with a circular orifice.

Locality.—St. Clair (Dunedin).

Though the branches usually spring from inside a hydrotheca, generally broken, they sometimes arise from the front of the hydrocaulus, just beneath a hydrotheca. One specimen shows a branch springing from inside a broken gonotheca.

The lower part of the hydrocaulus, below the proximal hydrotheca, is deeply and closely annulated or spirally thickened.

This species is allied to *S. rentoni* Bartlett, but differs in many important respects, as will be seen by a comparison of the description of the two species.

The points of attachment of the caecum of the hydranth are in the same position as in *S. rentoni,* and marked in the same way by a faint ridge with minute chitinous processes.

Sertularella procera, n. sp.
(Plate I., Figs. 5-5*d*.)

Colony tall and slender, attaining a height of 22 cm., tapering very gradually towards the apex. Main stem giving rise to a few

principal branches of the same structure as itself. Main stem and principal branches fascicled, except in distal parts. Main stem and branches giving rise on all sides to irregularly placed pinnae (the longest of which attain a length of about 1·3 cm.), except at the distal part where the pinnae all lie in the same plane and are more or less regularly alternate.

Pinnae sometimes strengthened in their proximal part by a tube running out from the fascicled stem or branch, but otherwise not fascicled, themselves pinnate or bipinnate, or with somewhat irregular sub-dichotomous ramification; the more regular forms with the sub-pinnae alternate; usually three hydrothecae (including one in the axil) between every two sub-pinnae or sub-dichotomous branches.

Internodes of stem and main branches usually bearing three hydrothecae; those of the pinnae and sub-pinnae bearing only one each. Pinnae not terminating in stolons.

Hydrothecae tubular or sub-conical, both series directed strongly to the front, curved outwards, sometimes somewhat abruptly; margin with three conspicuous teeth, one superior and two lateral, and an operculum of three pieces; no internal sub-marginal denticles. Points of attachment of caecum of hydranths extending very obliquely across the hydrothecae, reaching to nearly half way up in the front.

Gonothecae borne on the pinnae, large, obovate, surrounded by a number of prominent annular ridges, except on the proximal part of back which is smooth and adpressed to the pinna; distal portion of gonotheca not projecting forward; rising from the centre of the flattened end surrounded by the distal ridge a narrow, long, expanding tube; aperture usually central, rarely slightly eccentric.

The annular ridges on the gonothecae are similar to those of *S. johnstoni* and *S. pygmaea* except that they are somewhat more pronounced and the flange rather wider.

A fenestra is sometimes present at the base of the hydrothecae but more often absent. Similar fenestrae are numerous on the axillary tubes of the stem and branches, often on the abcauline side. Inter-communication between the tubes is frequent. Occasionally bridges like the letter H are met with between tubes not in contact with one another, though how they originate is not clear.

This species is closely allied to *S. divaricata* var. *subdichotoma*. A single pinna or two could not be distinguished from that species, but the manner of growth is altogether different.

Localities.—Bluff, several fine specimens; Stewart Island (J. F. Mulder), fragments.

Sertularella subarticulata (Coughtrey).

(Plate VII., Figs. *7-7b*.)

Locality.—Bluff, numerous specimens; Stewart Island, growing on "oyster" shells. This species has not hitherto been correctly figured.

SERTULARELLA IRREGULARIS, n. sp.

(Plate V., Figs. 1-1*b*.)

Hydrorhiza somewhat flattened, giving rise to shoots at close intervals.

Hydrocaulus unbranched or sparingly branched, attaining a height of about 5 mm., divided into short internodes each of which bears a hydrotheca.

Hydrothecae not arranged in two series, but in an irregular spiral, every fourth one approximately completing one turn, so that there are three irregular, longitudinal series. Hydrothecae adnate for about one-third of their height, tubular, slightly converging towards the mouth, slightly curved, the adcauline side being convex and the abcauline concave; aperture with three pointed, prominent teeth, one superior and two lateral, and an operculum of three triangular flaps. No internal sub-marginal denticles. Hydranth with about 16 to 20 tentacles, abcaulinary caecum weakly developed.

Gonothecae usually springing from the interior of a hydrotheca, but sometimes from the stem, ovate, marked with about 8 to 10 conspicuous transverse annulations which are not provided with a flange, terminating at the summit in a short tube which is sometimes slightly expanded at the orifice.

Locality.—St. Clair (Dunedin), growing on roots and stems of algae in rock-pools below the swimming pool.

SERTULARELLA CRASSIUSCULA Bale.

I collected specimens of this species, with gonothecae, at Bluff and New Brighton. In most of the hydrothecae in my specimens the marginal teeth are very shallow indeed, and the margin practically entire. Only in a comparatively few cases can I make out the four teeth, which are little more than undulations of the margin.

SERTULARELLA FUSCA, n. sp.

(Plate V., Figs. 2-2*b*.)

Hydrocaulus pinnate, or, occasionally, slightly bipinnate, attaining a height of about 15 mm., divided by oblique joints into internodes each bearing a hydrotheca.

Pinnae alternate, often crowded, one springing immediately below almost every hydrotheca of the hydrocaulus, both series directed in a marked degree to the front, the angle between them usually being 45° or less.

Hydrothecae alternate, both series directed in a marked degree to the distal side, the angle between the two series being usually a little less than 90°, adnate for a third, or less, of their height, constricted and somewhat thickened immediately below the mouth, especially on the adcauline side, where the margin is slightly

everted; abcauline side almost straight, adcauline side ventricose; margin with three prominent, rounded teeth, and an operculum of three pieces; three small and often inconspicuous internal submarginal denticles.

Gonothecae not present.

Locality.—St. Clair (Dunedin), in rock-pools below the swimming pool.

In several of the specimens there spring, from immediately below the base of one or more of the proximal hydrothecae,

	S simplex St. Clair Dunedin	*S. simplex* Auckland Harbour	*S. robusta* var. *quasiplana*
Hydrotheca			
length - - -	0·40 - 0·52	0·42 - 0·54	0·50 - 0·55
greatest diameter -	0·20 - 0·25	0·25 - 0·32	0·29 - 0·33
diameter at mouth (*c*) -	0·14 - 0·20	0·17 - 0·20	0·15 - 0·20
proportion adnate -	⅓ - ½	about ½	about ½
Internode			
length - - -	0·36 - 0·62	0·45 - 0·94	0·55 - 0·82
diameter (*d*) - -	0·15 - 0·20	0·13 - 0·16	0·15 - 0·16
Gonotheca			
length - - -	1·24 - 1·70	?	1·36 - 1·72
diameter - - -	0·60 - 0·83	?	0·77 - 0·90
	S robusta forma typica (*a*)	*S. angulosa* Bale (*b*)	*S. robusta* var. *flucticulata*
Hydrotheca			
length - - -	0·45 - 0·60	0·57 - 0·60	0·65 - 0·75
greatest diameter -	0·23 - 0·37	0·29	0·34 - 0·37
diameter at mouth (*c*) -	0·16 - 0·22	0·16 - 0·19	0·22 - 0·25
proportion adnate -	⅓	⅓ - ½	about ⅓
Internode			
length - - -	0·45 - 1·00	0·50 - 0·60	0·45 - 0·65 (*e*)
diameter (*d*) - -	0·15 - 0·21	0·17	0·18 - 0·30
Gonotheca			
length - - -	1·95	?	1·60 - 1·92 (*f*)
diameter - - -	1·00	?	1·20 - 1·35 (*f*)

(*a*) Measurements taken from specimens from Bluff and Stewart Island.
(*b*) Measurements taken from Bale's figure.
(*c*) Measured across the narrowest part.
(*d*) Half way between base of hydrotheca and proximal end of internode.
(*e*) Proximal internode of branch often attains 1·10 mm.
(*f*) From robust specimen from Bluff. Other specimens vary from 1·30 mm. × 0·85 mm. to 1·80 mm. × 1·0 mm.

stolons which turn downwards, but not in contact with the stem. In one example one of these reaches the hydrorhiza, and anastomoses with it.

Sertularella simplex-robusta Group.

The New Zealand forms belonging to this group are very difficult to separate from one another. Though *S. simplex* (Hutton), at the one end of the group, and *S. robusta* var. *flucticulata*, n. var., at the other, are so different even to the naked eye that no one could have any difficulty in separating them, there are numerous intermediate forms connecting them, which merge gradually into one another.

One great difference between the two above named is in the size of the hydrothecae, but the table of measurements on the opposite page shows how completely the gaps between them are filled up by other forms. The measurements are in millimetres.

Sertularella simplex (Hutton).

(Plate VI., Figs. 1-1*d*, 2-2*e*.)

Hutton's description (1872) of this species under the name of *Sertularia simplex* is not very full, and could easily include several forms which undoubtedly belong to a distinct species, though where to draw the line between them is not easy to decide. Coughtrey (1874) adds to Hutton's description sufficient further details to fix the typical form more satisfactorily. He, however, includes under this name two other forms, which he figures (1874, pl. xx., figs. 9 and 10), the latter of which he afterwards (1875) describes as a distinct species under the name of *Sertularella robusta.* The second form he describes as having faint, shallow grooves, generally three in number, that cross the hydrotheca.

It is very difficult indeed to decide to which species some of the forms in my collection belong, as there are so many intermediate forms, differing from one another in small details, but all of them having the general characteristics of the typical form.

The figure and description given by Bale (1924) may be taken as illustrating the typical form of the species. The hydrothecae of the specimens collected by me at the entrance to Auckland Harbour agree with his figure and description, but, though it was the most common species on the beach, I failed to find a gonotheca.

Hutton (1872) says "Hydrothecae distant," and many of my specimens agree with this. There is, however, considerable variation in this respect even in a single colony. Figs 1 and 1*a* are drawn from two shoots springing from the same hydrorhiza, and illustrate how considerable the variation may be.

The hydrorhiza anastomoses very freely; and my Auckland specimens show a considerable number of single hydrothecae growing from the hydrorhiza. No doubt they are the beginnings of new shoots which would ultimately develop, but in their present form they remind one forcibly of Allman's untenable genus

Calamphora. The hydrorhiza in these specimens is not flattened to any appreciable extent.

Specimens growing in tide pools at St. Clair (Dunedin) differ somewhat from the former, the hydrothecae being smaller, and usually directed more to the front, and slightly less of it being adnate. The gonothecae are also different from the typical form as figured by Bale, inasmuch as the tubular neck is absent. They have four conical projections at the summit, but these are not well developed. (See Fig. 2*c*.) The difference between the two forms is not sufficient to warrant the constitution of a new species in the case of such a variable hydroid as the present.

Stechow (1923) has figured quite a number of species belonging to this group, all of which have four external teeth and three internal submarginal denticles, as having one superior, one inferior, and one lateral internal denticle. I feel sure, however, that he has done this inadvertently. Bale describes the denticles as being "two within the two upper emarginations of border, and the third below inferior marginal tooth," and, in all probability, this is the arrangement of the internal denticles in all species having four teeth and three internal denticles. Plate VI., Fig. 1*d*, shows the appearance, when looking straight into the aperture, of the hydrotheca. The external teeth are not apparent in this figure, as they face directly towards the observer, but their position is indicated by the angles at the bases of the triangular flaps of the operculum, *a* and *b* representing the positions of the superior and inferior marginal teeth respectively, and *c* and *d* those of the lateral.

Hutton says in his original description that this species is "simple or rarely branched." I have a small branched specimen from St. Clair that I consider belongs to this species. It shows considerable variation both in the length of the internodes and in the manner in which the hydrothecae lie. In some shoots both series project to the front in a marked degree; in others the two series lie almost in the same plane. In this specimen the gonothecae differ somewhat from those already described, being, as a rule, narrower. None of them possesses more than three projections at the summit. (See Figs. 2*b*-2*d*.)

All the above described forms have the hydrothecae entirely destitute of any transverse undulations, and I consider that the forms with undulated hydrothecae should not be assigned to this species.

Sertularella robusta Coughtrey.

(Plate VI., Figs. 3-3*c*.)

Of the three forms originally assigned by Coughtrey to *Sertularia simplex* I include under the present species those figured by him (1874, pl. xx., figs. 9, 10). He included only Fig. 10 under the name *Sertularia robusta,* apparently leaving Fig. 9 as *Sertularia simplex.* These are what he refers to as the "several pigmy

varieties in which the hydrothecae are transversely wrinkled." I take it that the word 'pigmy' here refers to the height of the colony, and not to the size of the hydrothecae, because reference to his figures shows that the hydrothecae of Fig. 9 do not differ appreciably in size from those he figures as the typical form (Fig. 8). In his Description of Plate he says, "All objects magnified 50 diameters except where otherwise specified." This, as Mr. Bale has pointed out to me, is obviously incorrect. The length of a hydrotheca of the typical form, in my collection, of *S. simplex*, which varies very little from that figured by Bale, is about 0·5 mm. Assuming that the hydrothecae of the typical form of *S. simplex* as figured by Coughtrey are about the same length, his figures of *S. simplex* and its variety *S. robusta* cannot be magnified more than about 18 diameters.

I have endeavoured to separate the forms with undulated hydrothecae into more than one species, but, although the large and small forms differ very considerably from one another in size and general appearance, I have so many intermediate forms that I am unable to do so satisfactorily, and must be content for the present in describing as varieties certain forms that differ somewhat from the typical form. At first it seemed that there was a decided gap between the largest of the small forms and the smallest of the large, but this is filled by *Sertularella angulosa* Bale (1893, p. 102, pl. iv., fig. 6), which, I think, must be regarded as a variety of *S. robusta* (*Sertularella robusta* var. *angulosa*). In the smaller forms the hydrothecae are about 0·5 mm. in length, and differ from *S. simplex* in having transverse ridges. In *S. angulosa* the hydrothecae are about 0·6 mm. in length. In this form the stem is zig-zag. In many of my New Zealand specimens also the stem is zig-zag (though most of them are almost, if not quite, straight), and one specimen so closely resembles Bale's figure as to leave no doubt whatever in my mind concerning the identity of the species.

As it is quite impossible to say definitely which form Coughtrey had before him and used as his type of *S. robusta,* I am assuming that it was the more common form, and not either of the varieties I am describing under the names of var. *quasiplana* and var. *flucticulata*. Both of these are comparatively rare, while the common form is so plentiful that Coughtrey could not possibly have missed it.

The full description of a typical specimen of *Sertularella robusta* is as follows:—Shoots simple, attaining a height of 10 mm., divided by slightly oblique joints into internodes which vary considerably in length, each bearing a hydrotheca on its upper part. Hydrothecae adnate for about one-third of their height, large, divergent, barrel-shaped, but smaller towards the summit, usually more ventricose on the adcauline than the abcauline side, with about six distinct sharp, transverse ridges, completely surrounding them, but usually becoming less distinct on the abcauline side; aperture expanding, with four well-defined teeth, aperture some-

times at about right angles to the length of the hydrotheca but often with the inferior tooth projecting further than the others; three internal, compressed, vertical, submarginal denticles, two of which are within the two upper emarginations of the border, and the third opposite the inferior marginal tooth.

Gonothecae large, borne sometimes on the hydrocaulus and sometimes on the hydrorhiza, ovate, with several distinct cross undulations, upper part sometimes in the form of a tubular neck, which, however, is not always distinctly present; summit usually with about four conical projections.

Locality.—Bluff, and on "oyster" shells from Stewart Island. I have already referred to the single hydrothecae that are found on the hydrorhiza of *S. simplex*. In the present species single hydrothecae are also met with quite commonly, and remind one even more forcibly of Allman's genus *Calamphora*.

SERTULARELLA ROBUSTA var. QUASIPLANA, n. var.

(Plate VI., Figs. 4, 4*a*.)

I have separated *S. robusta* from *S. simplex* on account of the presence in the latter and the absence in the former of transverse undulations on the hydrothecae. The present form seems to be on the border line. At first sight it looks like a rather robust form of *S. simplex,* but closer examination reveals the presence of three or four transverse rugae completely surrounding the hydrotheca. It is true they are often rather faint; in fact, in some hydrothecae, such as the one figured, they would be likely to be overlooked but for the presence of minute diatoms which grow thickly along the shallow depressions between the ridges. This variety differs from the others not only in the above respect, but also in having the hydrothecae usually broader at the base, in proportion to their height, than the others. They are often adnate for as much as one-half of their height. In some specimens I have found the superior tooth projecting slightly more than the others, but usually the mouth is at right angles to the length of the hydrotheca. The teeth are, as in the typical form, well defined. My specimens attain a height of 13 mm.

The gonothecae do not differ from the typical form in any important particular. They are, however, somewhat larger.

Locality.—Island Bay.

SERTULARELLA ROBUSTA var. FLUCTICULATA, n. var.

(Plate VI., Figs. 5, 5*a*.)

This variety differs from the others mainly in its much greater size in all its parts, and only for the existence of *S. angulosa* Bale (1893, p. 102, pl. iv., fig. 6), I would have no hesitation in ranking it as a distinct species. The rugae appear like little waves on the adcauline side (hence the proposed name of the variety), but rarely

extend more than half way round the hydrotheca, the abcauline side being almost, if not altogether, free from undulations. The internal submarginal denticles are very large and well developed, but form very thin vertical plates. Usually the mouth of the hydrotheca is not at right angles to its length, the inferior tooth projecting considerably more than the others. The teeth are rarely well developed, and are often no more than a slight wave in the otherwise entire but oblique peristome.

The gonothecae are broader than those found on the other varieties, and are borne on stem and branches.

Unlike the other forms belonging to this species the hydrophyton branches rather freely, but the branching is quite irregular. There is considerable variation in the length of the internodes, even in the same colony. In one specimen they vary from 0·45 mm. to 0·85 mm.

Locality.—Bluff.

Thuiaria farquhari Bale.

(Plate VII., Fig. 4.)

A fine specimen of this species collected at Bluff densely clothes the stem of an ascidian for several inches.

Thuiaria buski Allman.

(Plate VII., Figs 1-1*c*.)

Hydrocaulus not fascicled, attaining a height of about 3 inches (*fide* Allman), straight or almost so, unbranched, pinnate. Stem usually thick, divided by slightly oblique nodes into internodes of variable length, each bearing from 1 to 5 pairs of hydrothecae. Pinnae irregular, usually with a tendency to alternate disposition, rarely opposite, stout, divergent at nearly right angles, borne on slender apophyses from which they are separated by a rather oblique, conspicuous node; usually divided into 2 or 3 long internodes each bearing from 4 to 8 (sometimes up to 11) pairs of hydrothecae; nodes oblique, very rarely transverse.

Hydrothecae in pairs, strictly opposite both on hydrocaulus and pinnae, adnate in front, widely separated behind, most of their length vertical, upper portion turned outward and narrowed, aperture vertical, widened laterally, with two lateral lobes, facing outward and forward; edge of peristome thin, especially on the adcauline side, where the sinus between the lateral lobes is filled up by a very thin prolongation of the wall of the hydrotheca; sometimes a slight broad internal thickening of the perisarc just inside the peristome on the abcauline side, but no well developed internal denticle.

Pairs of hydrothecae usually closely approximated, sometimes actually touching, on the pinnae; more separated on the hydrocaulus.

Gonothecae borne on the front of the pinnae, near the base of same, ovoid, about 2·5 mm. in length, aperture round, entire, on a very short neck.

Colour of perisarc, dark brown.

Locality.—Island Bay and Bluff.

Allman's (1876) description and figures of this species are faulty. He describes and figures the pinnae as being divided into short internodes, each of which bears a single pair of hydrothecae only, and his figure shows the joints as being transverse. At Mr. Bale's request Captain A. K. Totton, M.C., of the British Museum (Natural History), has examined Allman's type, and in a letter, which the former has kindly placed at my disposal, writes as follows:—"The successive pairs of hydrothecae on the type of *D. buskii* are closely approximated though not quite touching, but there is *not* a node between each pair. It would be unwise to say more about the nodes than this, because the type specimen is a poor one, very imperfect and much overgrown."

In my experience nodes in the pinnae of Sertulariidae are never found in the position shown in Allman's figure, immediately above the base of the hydrothecae. The explanation of his mistake is doubtless that he examined a pinna lying approximately in the position shown in my Fig. 1*c*, and mistook for a node the base of the hydrotheca on the further side of the pinna. In his Fig. 4 an oblique view of the pinna is shown. His Fig. 7 is a lateral view, not "oblique," as he calls it. This is borne out by the relative distances between the hydrothecae and the back of the pinnae. The importance of this is that if his Fig. 4 showed a true lateral view of the pinna, the distance by which the hydrothecae are separated at the back would be greater than it really is. I have searched my material for a transverse node such as he shows, but find that transverse nodes in this species are very rare, and when present occur, as one would expect, above the adnate part of the hydrothecae. Allman's figure would make them occur behind the adnate part.

In all my specimens the colour of the perisarc is very pale horn.

This species is allied to *T. bicalycula*, but differs from it in several respects, the most striking of which are that in the latter the hydrocaulus is much stouter and consequently the hydrothecae on it are far more widely separated at the back, these hydrothecae are not spaced regularly and not always in pairs, the apophyses are much stouter and are not separated from the pinnae by a conspicuous node, and on the pinnae of the latter species the pairs of hydrothecae are not placed so closely together.

THUIARIA BUSKI var. TENUISSIMA, n. var.

(Plate VII., Fig. 2.)

Specimens from Island Bay and Bluff, attaining a height of 35 mm., differ sufficiently from the typical form to be ranked as a distinct variety. The whole hydrophyton is more slender, the

hydrocaulus being little, if at all, thicker than the pinnae and scarcely distinguishable from it in arrangement of the hydrothecae. The hydrothecae are somewhat smaller and the pairs are not so closely approximated. The hydrocaulus and pinnae being narrower, the hydrothecae are not so widely separated at the back. The pinnae are much shorter than those of the average specimen of the typical form, and the node between pinna and apophyse is more oblique. The apophyses are much longer and more slender. To the eye this variety closely resembles Allman's natural size figure of *T. buski* (Allman, 1876, pl. xiv., fig. 3).

Gonothecae not present.

THUIARIA SPIRALIS, n. sp.

(Plate VII., Figs. 3-3*e*.)

Hydrocaulus attaining a height of 16 cm., arranged in a loose but fairly regular spiral, sparingly branched, pinnate. Stem thick, fistulous, divided by slightly oblique joints into internodes, each bearing from 1 to 5 pairs of hydrothecae. Pinnae quite irregular, occasionally opposite, stout, divergent usually at an angle of 60° or more, borne on short stout apophyses from which they are separated by a conspicuous oblique node; pinnae themselves giving rise to secondary pinnae borne on similar but somewhat more slender apophyses; pinnae and secondary pinnae stout, usually divided by slightly oblique nodes into internodes, each bearing from 1 to 7 (sometimes up to 11) pairs of hydrothecae, but sometimes undivided.

Hydrothecae in pairs, strictly opposite, in contact in front, widely separated at the back, especially those on the hydrocaulus, most of their length vertical, upper portion turned outward and forward, and narrowed; aperture vertical, widened laterally, with two lateral lobes; edge of peristome thin, especially on the adcauline side in the sinus between the lateral lobes, slightly thickened just inside the abcauline side, but with no well developed internal denticle.

Pairs of hydrothecae fairly closely approximated on the pinnae, but widely separated on the hydrocaulus.

Colour of perisarc, dark brown.

Gonothecae borne on the front of the pinnae, near the base of same, large, ovoid, about 2·5 to 2·7 mm. in length, and 1·1 to 1·3 mm. in diameter; aperture round, entire, on a very short neck, scattered, vertically flattened, irregular denticles sometimes projecting into the interior round the neck, but not always present.

The spiral habit and dark colour of this species at once makes it easily distinguished from *T. buski* and *T. bicalycula,* to which it is allied. It also differs from the latter in the regular arrangement of the hydrothecae on the hydrocaulus, and the oblique joints between the pinnae and the apophyses. The hydrothecae on the pinnae are not so closely approximated as in *T. buski.*

The pinnae, following the twisting of the hydrocaulus, are given off in all directions, and do not lie in a single plane. The cauline hydrothecae also spirally follow the twisting of the hydrocaulus.

Sertularia episcopus (Allman).

I found specimens of this species growing profusely over algae washed ashore at Island Bay.

Sertularia fasciculata (Kirchenpauer).

I collected a specimen of this species at Island Bay, and another at Bluff.

Sertularia bispinosa (Gray).

A specimen of this species is in the collection of the late Mr. J. F. Mulder, but the locality is not stated. The gonothecae contain a ring of tiny internal denticles. One of the gonothecae is totally destitute of "shoulders."

Sertularia trispinosa Coughtrey.

(Plate V., Fig. 3.)

I found numerous specimens, with gonothecae, at St. Clair (Dunedin), and Bluff.

Attention has been drawn (Mulder and Trebilcock, 1914, p. 38) to the presence of a tiny aperture, from which sometimes protrudes a short and delicate tube, in the perisarc of the infrathecal chamber of *S. minima, S. minuta,* and allied species. This aperture is also found in a similar position in *S. trispinosa,* but in no case can I find any trace of a tube. In this species I have noticed protruding from the aperture a small mass of (?) protoplasm, but whether it is a sarcostyle or not I am unable to determine, as the soft parts of my specimens of this species are not in sufficiently good state of preservation.

In most cases in *S. trispinosa* these apertures are missing, and, when present, I have not found them paired.

Stechow treats these structures as nematophores, and creates a new genus *Nemella* for the reception of the species possessing them.

Sertularia trispinosa var. inarmata, nov.

(Plate V., Fig. 4.)

A specimen, collected by me at Island Bay, having a large number of shoots, differs from the typical form in its gonothecae which are totally destitute of "horns" or even "shoulders." At first I felt disposed to treat it as merely an accidental variation, especially as in some instances there is a slight irregularity in outline of the gonothecae at the spot usually occupied by the "horns."

However, after examining the whole of the gonothecae, of which there are a considerable number, and among which I find no exception, I have come to the conclusion that the difference is sufficient to warrant this form being named as a distinct variety.

In the trophosome the variety does not differ in any respect from the typical form.

Sertularia minima Bale.

(Plate VII., Figs. 5, 5*a*.)

I have specimens of this species from Island Bay (Wellington), St. Clair (Dunedin), and Bluff. In specimens from all three localities the tiny apertures and tubes are found springing from the infrathecal chambers. In many of the specimens from St. Clair two apertures and tubes are found instead of one, and similar structures are also found on the hydrorhiza, but in the latter case the tubes are much longer.

Two apertures, with tubes, are also found in some of the Bluff specimens. In the latter the gonothecae sometimes have and sometimes are without the internal submarginal denticles.

The Island Bay specimens belong to the variety *pumiloides*.

Sertularia divergens Busk.

A few specimens of this species were growing on an "oyster" shell from Stewart Island. "*Tridentata xantha*" Stechow (1923*a*, p. 64; 1925, p. 236, fig.) does not belong to this species, but is probably a young form of *Sertularia unguiculata* Busk.

Sertularia unguiculata Busk.

I collected specimens of this species at St. Clair and Bluff, those from the latter locality having gonothecae. They do not differ in any respect from the average Victoria specimen.

Dynamena quadridentata (Ellis and Solander).

A few fragmentary specimens of this species from "oyster" shells from Stewart Island are in the collection of the late Mr. J. F. Mulder. Not hitherto recorded from New Zealand.

Stereotheca elongata (Lamouroux).

Bale (1924) states that "specimens from Lyttelton, in Professor Chilton's collection, do not differ in any respect from the small form abundant on the southern Australian coast." My New Zealand specimens, on the contrary, which I collected at Island Bay, St. Clair (Dunedin) and Bluff, belong to the larger variety, and most of them are more robust than the average large southern Australian specimens, and usually branch more freely.

Fam. PLUMULARIIDAE.

PLUMULARIA PULCHELLA Bale.

I collected a single specimen of this small species, with gonothecae, growing on *Stereotheca elongata*, at Bluff. It differs in no respect from the form usually found on the Victorian coast. As in the Victorian specimens, the gonothecae are of two sizes, one about twice the length of the other. Possibly they are of different sexes, but in the absence of gonangial contents I am unable definitely to decide that point. This species has not hitherto been recorded from New Zealand.

PLUMULARIA SETACEA (Linn.).

I collected numerous specimens of this species at St. Clair and Island Bay.

PLUMULARIA SETACEOIDES Bale.

I collected numerous specimens of this species, with gonothecae, at Island Bay, St. Clair (Dunedin), and Bluff. It has not hitherto been recorded from New Zealand. The specimens do not differ materially from the average specimen from Victoria.

I have considerable doubt whether *Plumularia wilsoni* Bale (1926), (=*P. delicatula* Bale, not Busk, not Quelch) is specifically distinct from *P. setaceoides*, but must examine further specimens of *P. wilsoni* in a well preserved condition before coming to a definite conclusion. Some of my specimens from Island Bay, which had been washed ashore and dried, cannot be distinguished from the last named species, though others were undoubtedly *P. setaceoides*.

PLUMULARIA HYALINA Bale.

(Plate VI., Fig. 6.)

I collected specimens of this species at St. Clair, Island Bay, and Bluff. It has not hitherto been recorded from New Zealand.

This species has always been looked upon as possessing pinnae each bearing essentially a single hydrotheca only, and would thus be placed in Nutting's genus *Monotheca*. The better opinion seems to be that the retention of this genus is not warranted. In specimens collected at St. Clair and Island Bay I find an additional argument in favour of this view. Several of the pinnae bear two hydrothecae each, and are divided, like a typical *Plumularia*, into alternate long and short internodes, the former each bearing a hydrotheca, one median inferior and two lateral superior sarcothecae, and the latter each bearing a single median sarcotheca only.

The retention of the genus *Monotheca* would doubtless be very convenient, but the existence of forms such as the above is a strong argument against it.

THECOCAULUS MINUTUS, n. sp.

(Plate VII., Figs. 6, 6*a*.)

Hydrocaulus attaining a height of about 5 mm., not fascicled, unbranched, lower part usually destitute of appendages, remainder divided into alternate hydrothecate and non-hydrothecate internodes, the latter usually short. Pinnae, the proximal two usually opposite, the remainder alternate, bearing from one to three hydrothecae, divided into alternately long and short internodes of which only the former bear hydrothecae.

Hydrothecae free for two-thirds of their length, campanulate, longer than broad, broad at base, slightly constricted at the rear near the margin; margin smooth, circular slightly everted at the rear.

Sarcothecae bithalmic, canaliculate, narrow at base, one median below each hydrotheca, and a pair of laterals above it, one median on each intermediate internode of stem and pinnae, and sometimes one median above the caulinary hydrothecae, on the upper part of the hydrothecate internodes.

The pinnae are each borne on a prominent apophyse, which springs from beside each caulinary hydrotheca.

The first internode, and sometimes the second, are short, and bear no appendages. The intermediate internodes, both on the stem and pinnae, vary in length, but are usually short. Sometimes on the stem two intermediate internodes are found in succession.

The joint above each intermediate internode, both on stem and pinnae, is oblique.

The lateral sarcothecae rise to about the level of the margin of the hydrotheca. Gonosome, not present.

Locality.—St. Clair (Dunedin).

THECOCAULUS HETEROGONA Bale.

Mr. Bale has kindly sent me a specimen of this interesting species. In the axil at the back of each hydrotheca there is a sarcostyle protected by an extremely delicate, monothalmic, rudimentary, bract-like sarcotheca, shaped something like the terminal half of the bowl of a spoon. These sarcothecae are difficult to detect anywhere, but particularly so on the pinnae; in fact, I could distinguish them there in only a few instances.

AGLAOPHENIA ACANTHOSTOMA Allman.

I collected several specimens of this species at Bluff and St. Clair (Dunedin).

AGLAOPHENIA LAXA Allman.

(Plate V., Figs. 5-5*b*.)

I collected numerous specimens of this species with corbulae at Island Bay. The largest specimen attains a height of nearly 60

mm. In my specimens the teeth of the hydrothecae are more rounded than shown by Bale (1924, p. 260, fig. 15).

There are two forms of this species represented in my collection, one with the hydrocladia lax, there being about 26 to the cm., the other with close-set hydrocladia, as many as 46 to the cm. In general appearance these two forms are so different as to lead one at first to the conclusion that they belong to different species, but, apart from the distance between hydrocladia I can detect no difference between them, and, as the length of the hydrocladial internodes varies in some specimens, there is little doubt that examination of a large number of specimens would reveal intermediate forms connecting these two extremes.

Bale's conjecture that the gonosome, when found, would prove to be of the same character as in *A. acanthocarpa* and *A. divaricata* I find to be correct.

THECOCARPUS FORMOSUS (Busk) var. INARMATUS, nov.

(Plate V., Figs. 6, 6*a*.)

I was fortunate in collecting a number of specimens of this apparently rare species at Island Bay. M. Billard, to whom I submitted specimens, has kindly compared them with his specimens from Madagascar, and writes me as follows:—

"Malgré des différences, je crois qu'il s'agit de la même espèce. Dans vos échantillons, seule la dent latérale adcaulinaire est bifurquée à tel point même qu'elle apparaît comme en formant deux; les deux autres situées du côté de la médiane ne le sont pas du tout. Je dois dire que mon dessin représente un cas extrême et que dans toutes les hydrothèques les dents latérales voisines de la médiane ne sont pas toujours aussi franchement bifurquées; le dessin de Marktanner donne un cas intermédiaire entre ce qui existe chez mes exemplaires africains et vos exemplaires néo-zélandais. Dans ceux-ci j'ai noté le plus faible développment du repli intrathécal et du processus spiniforme médian. Dans les échantillons que vous possédez, les hydroclades sont-ils terminés par une épine ayant à sa base une dactylothèque? Je n'ai pas observé ce détail dans les spécimens que j'ai reçus. Il-y-aurait lieu je crois de faire de la forme néo-zélandaise une variété distincte."

Billard's letter leaves little for me to add in the description of this variety. In none of my New Zealand specimens are the hydrocladia terminated in a spine.

The median spiniform processes of the hydrothecae are hollow, and vary considerably in size.

Gonosome, not present.

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—*Saaba* (?) *scandens*, n. sp. ×15.
1*a*. Gonangium (?) of same. ×15.

Fig. 2.—*Orthopyxis formosa*, n. sp.
2. Showing flanged hydrorhiza, renovation of stem, and broad view of hydrotheca. ×20.
2*a*. Another hydrotheca, broad view. ×20.

2*b*. The same, narrow view. ×20.
2*c*. A large hydrotheca, with renovated margin. ×20.
2*d*. A thin walled specimen, showing hydranth. ×20.
2*e*. Transverse section through perisarc of stem, showing flattening and thickening. ×20.

Fig. 3.—*Sertularella rentoni* Bartlett. ×70.

Fig. 4.—*Sertularella macrogona,* n. sp.
4. Typical specimen. ×20.
4*a*. Front view. ×70.
4*b*. Side view. ×70.
4*c*. Hydrotheca, showing operculum. ×70.
4*d*. Gonotheca. ×15.

Fig. 5.—*Sertularella procera,* n. sp.
5. Part of typical colony. ×½.
5*a*. Part of pinna. ×35.
5*b*. The same showing fenestrae. ×35.
5*c*. A hydrotheca from the hydrocaulus. ×35.
5*d*. Gonotheca. ×15.

Plate II.

Fig. 1.—*Orthopyxis delicata,* n. sp.
1-1*d*. Hydrothecae, showing variation in size. ×50.
1*a*. Showing renovation of margin. ×50.
1*e*. Gonangium. ×15.
1*f*. Hydrotheca, viewed from above. ×50.

Fig. 2.—*Perisiphonia quadriseriata,* n. sp.
2. Complete specimen. ×½.
2*a*. Part of hydrocaulus and of one hydrocladium and the base of another, dissected after maceration in liquor potassi, showing part of three peripheral tubes. ×35.
2*b*. Part of hydrocladium, broad view. ×35.
2*c*. The same, narrow view. ×35.
2*d*. Three sarcothecae. ×110.

Plate III.

Fig. 1.—*Halecium corrugatissimum,* n. sp.
1. Complete colony, showing method of branching. ×15.
1*a*. Two hydrothecae. ×70.
1*b, c*. Hydrothecae, showing reduplication of hydrothecae. ×70.
1*d*. Young hydrotheca. ×70.
1*e*. Hydrotheca and gonotheca. ×70.
1*f*. Hydrotheca, ×110, to show thinness of perisarc.

Fig. 2.—*Halecium expansum,* n. sp.
2. Complete colony, showing method of branching, with hydranths, one of them young. ×15.

2*a*. The same species, showing normal method of branching. ×50.
2*b*, *c*. Hydrothecae. ×110.

Fig. 3.—*Halecium lenticulare*, n. sp.
3. Complete colony, showing method of branching and position of gonothecae, the proximal one of which has been twisted on its stalk to show broad aspect. ×15.
3*a*. An example of vigorous reduplication of hydrotheca. ×15.
3*b*, *c*. Examples of irregular branching. ×35.
3*d*. Male gonotheca. ×15.

Plate IV.

Fig. 1.—*Halecium lenticulare*, n. sp.
1. Specimen from Island Bay. ×35.
1*a*. Specimen from St. Clair. ×50.
1*b*. Specimen from Bluff, showing delicate diaphragm, and reduplication of margin of hydrotheca. ×110.

Fig. 2.—*Halecium expansum*, n. sp.
2. Distal part of a colony, with hydranths, showing crowded state of hydrothecae. ×50.
2*a*. Another example of active branching. ×50.
2*b*. An example of unusually active renovation of hydrothecae. ×50.

Fig. 3.—*Campanulina humilis* Bale.
3. Simple form. ×50.
3*a*, *b*. Branched form, showing hydranths. ×50.
3*c*. Base of four tentacles, showing web. ×360.
3*d*. Tip of tentacle, showing nematocysts. ×360.

Fig. 4.—*Selaginopsis monilifera* (Hutton). ×15.
4*a*. A young hydrotheca of same, showing three-toothed margin. ×35.

Plate V.

Fig. 1.—*Sertularella irregularis*, n. sp. ×50.
1*a*, *b*. Gonothecae of same. ×35.

Fig. 2.—*Sertularella fusca*, n. sp. × 35.
2*a*. Another view of same. ×35.
2*b*. Hydrotheca. ×50.

Fig. 3.—*Sertularia trispinosa* Coughtrey, showing pore (*a*) in infrathecal chamber. ×50.

Fig. 4.—*Sertularia trispinosa* var. *inarmata*, n. var. Gonotheca. ×15.

Fig. 5.—*Aglaophenia laxa*. Allman. ×110.
5*a*. Hydrotheca, viewed from the front. ×110.
5*b*. Adcauline part of top of hydrotheca. ×200.

Fig. 6.—*Thecocarpus formosus* (Busk) var. *inarmatus*, nov. ×110.
6*a*. Front view of hydrotheca. ×110.

PLATE VI.

Fig 1.—*Sertularella simplex* Hutton. (Loc. Auckland.)
1, 1*a*. Specimens taken from same hydrorhiza. ×15.
1*b*. Typical hydrotheca. ×35.
1*c*. Single hydrotheca growing from hydrorhiza. ×35.
1*d*. Mouth of hydrotheca viewed from above, showing operculum, internal denticles, and position of (*a*) superior, (*b*) inferior, and (*c* and *d*) lateral teeth. ×50.

Fig. 2.—*Sertularella simplex* Hutton. (Loc. Dunedin.)
2. Part of hydrocaulus, showing unusual anastomosis. ×35.
2*a*. Hydrotheca from specimen with unusually massive walls. ×35.
2*b-e*. Gonothecae, showing extent of variation. ×35.

Fig. 3.—*Sertularella robusta* Coughtrey.
3. Typical hydrotheca from Island Bay. ×35.
3*a*. Typical hydrotheca from Bluff. ×35.
3*b*. Single hydrotheca growing from hydrorhiza, front view. (Loc. Bluff.) ×35.
3*c*. Gonotheca. (Loc. Island Bay.) ×15.

Fig. 4.—*Sertularella robusta* var. *quasiplana*, n. var. (Loc. Island Bay.) ×15.
4. Typical hydrotheca. ×35.
4*a*. Gonotheca. ×15.

Fig. 5.—*Sertularella robusta* var. *flucticulata*, n. var.
5. Branched form with gonothecae. ×20.
5*a*. Typical hydrothecae. ×42.

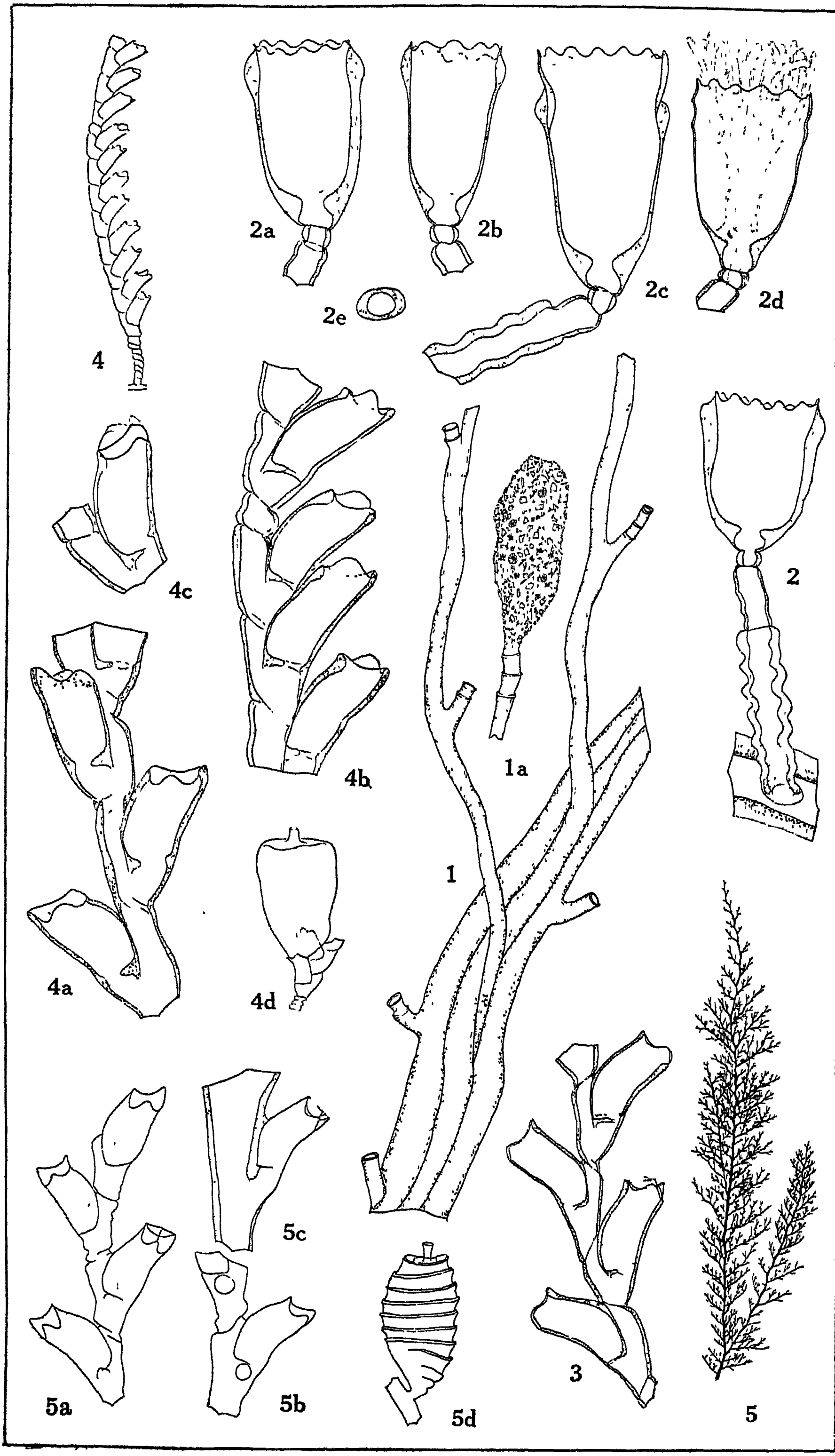
Fig. 6.—*Plumularia hyalina* Bale, showing hydrocladium bearing more than one hydrotheca. ×50.

PLATE VII.

Fig. 1.—*Thuiaria buski* (Allman). (Loc. Island Bay.)
1. Part of average pinna. ×15.
1*a*. Pinna without joints, side view. ×15.
1*b*. Part of pinna with two kinds of nodes, side view. ×15.
1*c*. Part of pinna showing both series of hydrothecae. ×15.

Fig. 2.—*Thuiaria buski* var. *tenuissima*, n. var. ×15.

Fig. 3.—*Thuiaria spiralis*, n. sp.
3. Distal half of type specimen. Nat. size.
3*a*. Part of hydrocaulus showing spiral arrangement of hydrothecae. (The hydrocaulus has been straightened in the drawing to economize space.) ×15.



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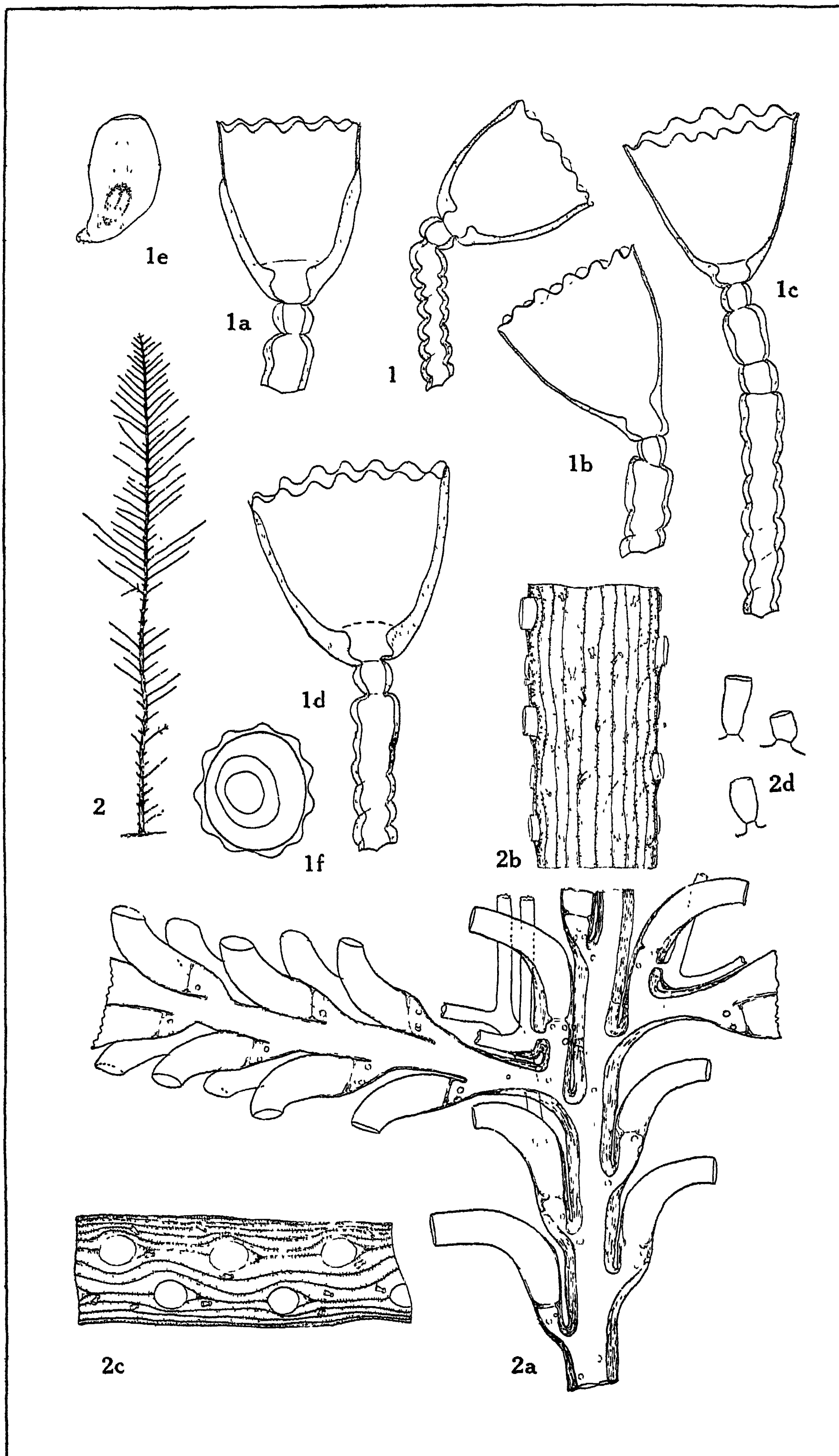

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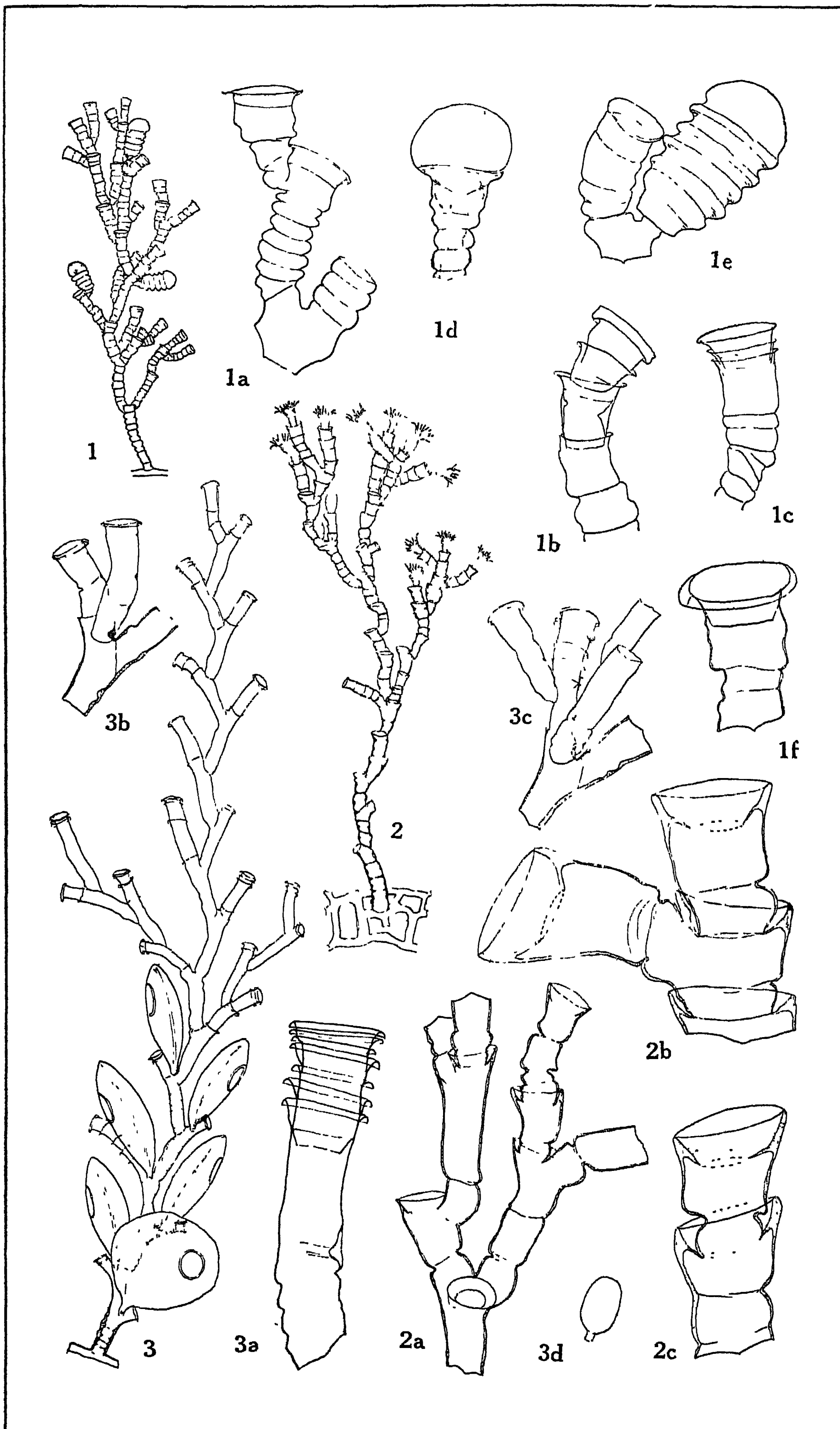

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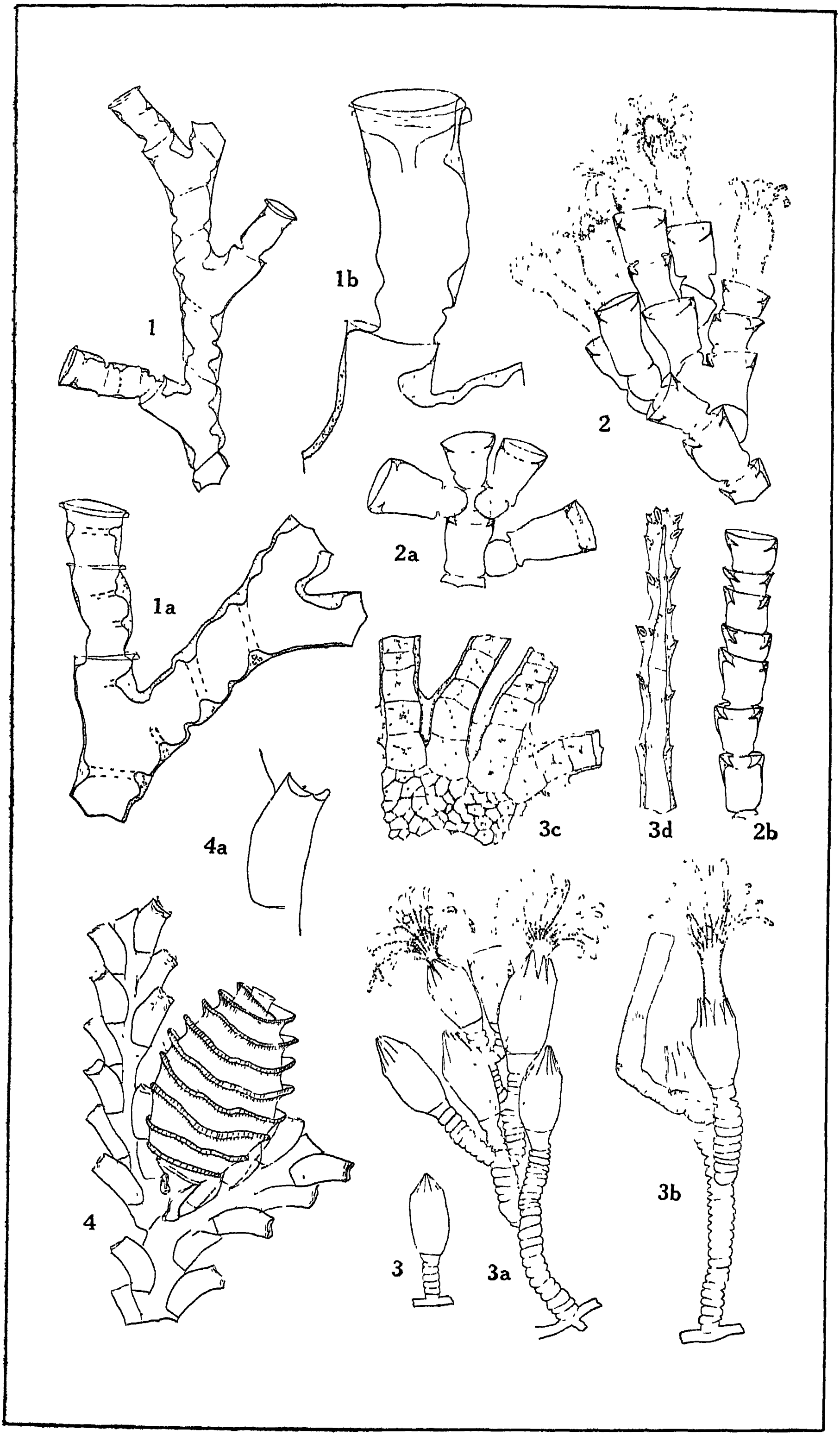

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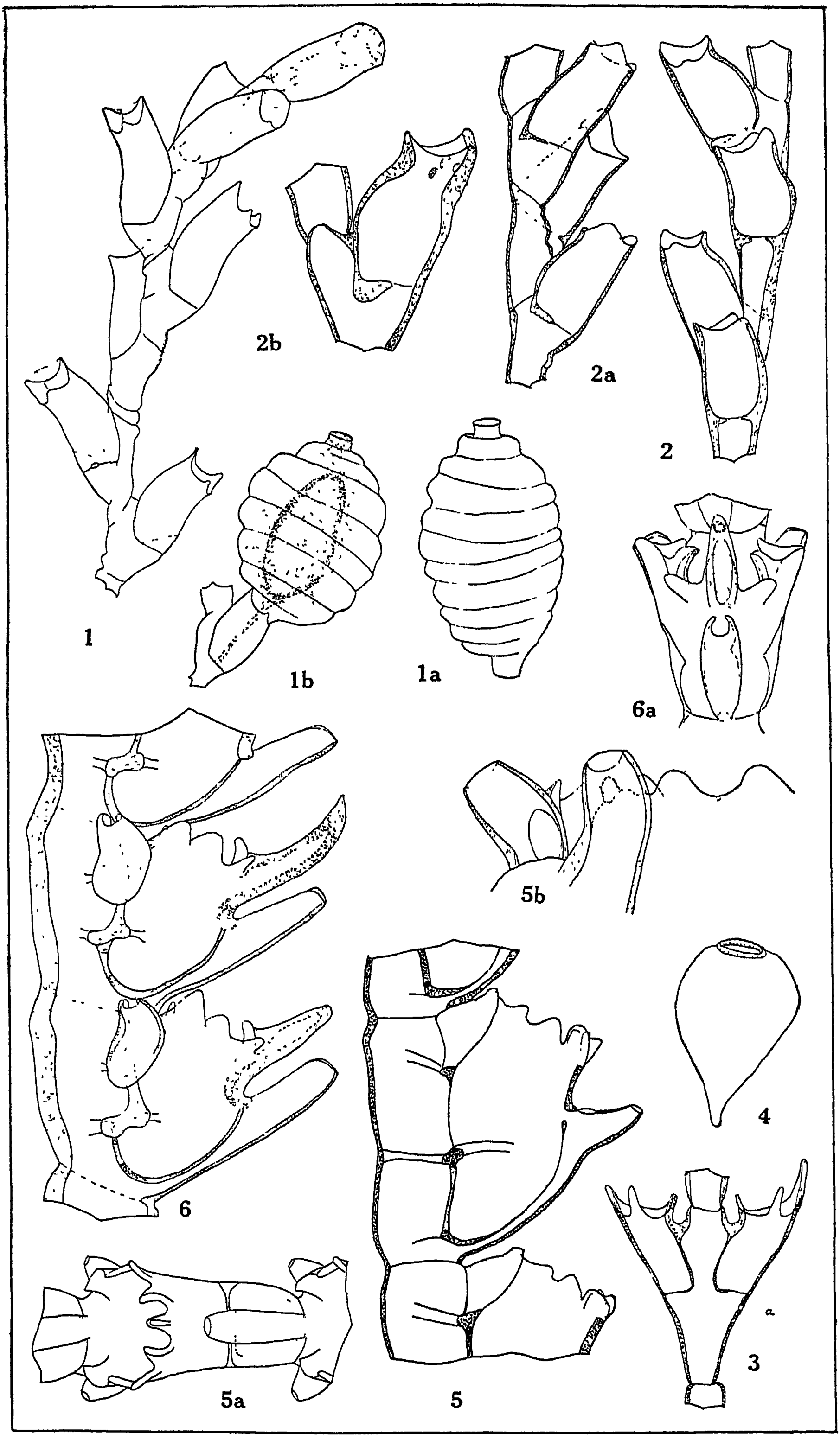

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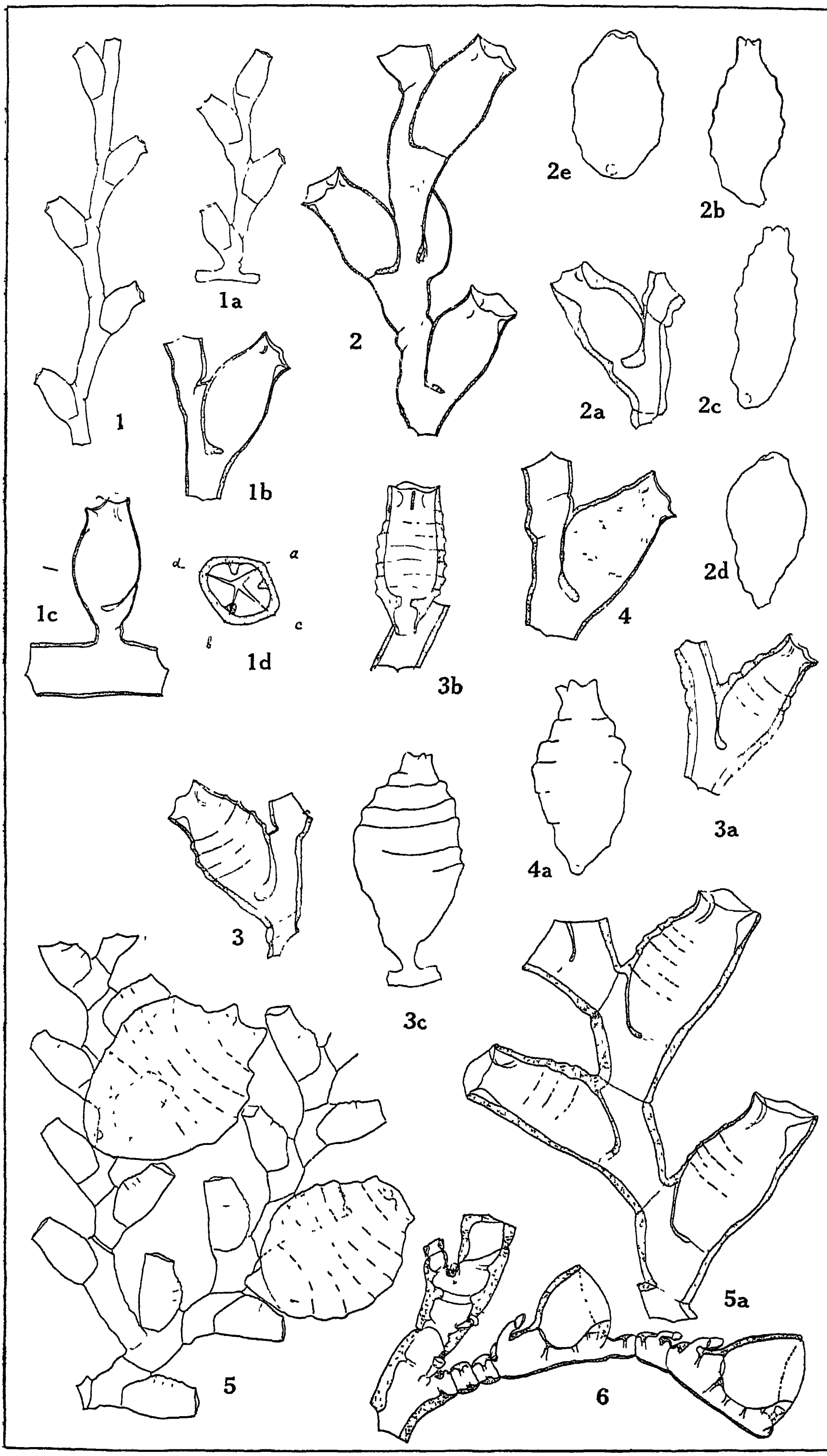

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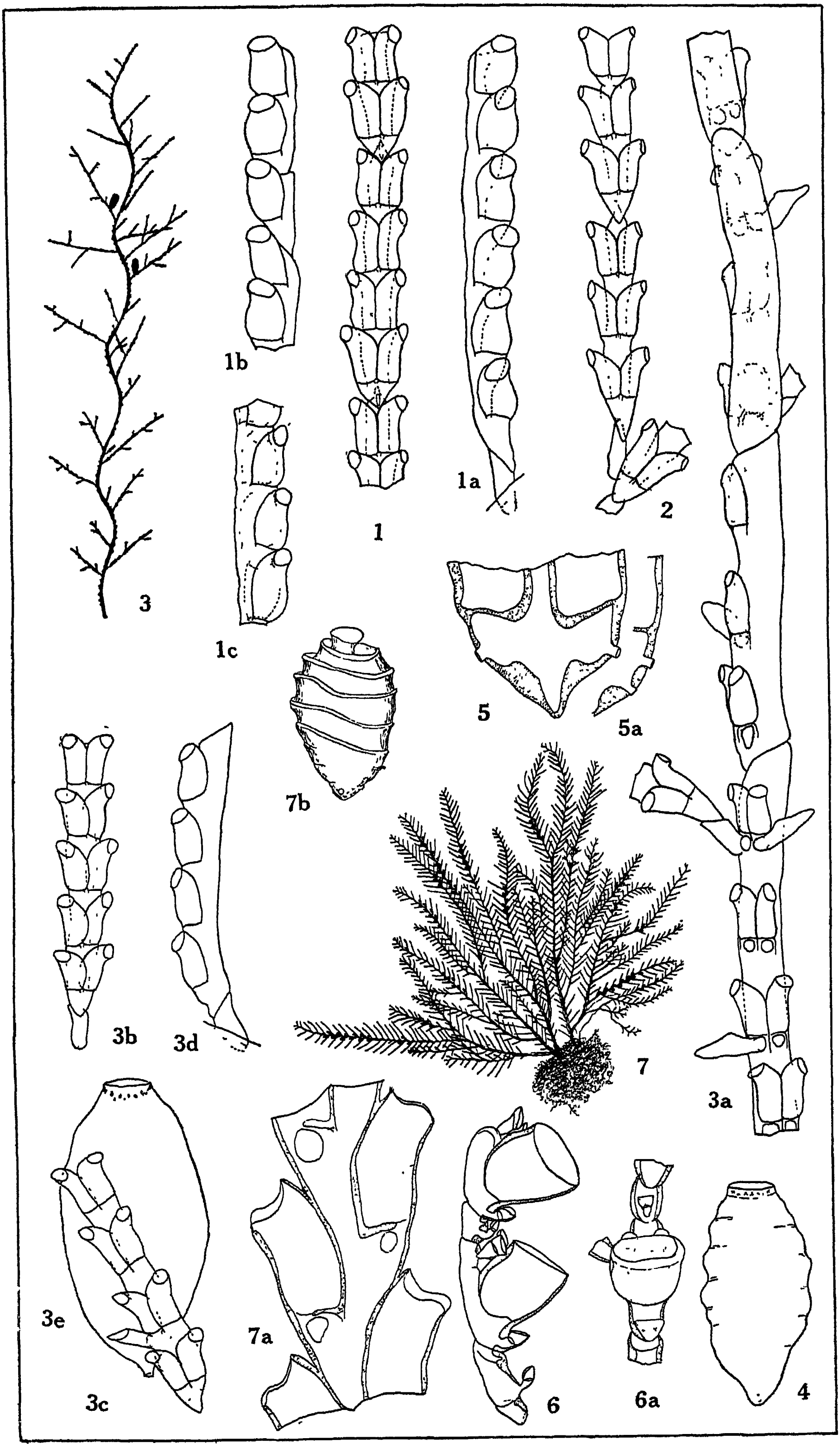

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Fig. 4.—*Thuiaria farquhari* Bale, gonotheca. ×15.

Fig. 5.—*Sertularia minima* Bale.

5. Infrathecal chamber, showing a pair of pores, with tubes. ×110.

5*a*. Side of another specimen, showing two pores on one side. ×110.

Fig. 6.—*Thecocaulus minutus,* n. sp.

6. Hydrocladium. ×50.

6*a*. Front view of part of hydrocladium. ×50.

Fig. 7.—*Sertularella subarticulata* (Coughtrey).

7. Small complete colony. ×½.

7*a*. Hydrothecae. ×50.

7*b*. Gonotheca. ×15.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. I., 1928.]

ART. II.—*The Diurnal and Annual Fluctuations of Temperature in the Interior of a large Tree.*

By A. O. BARRETT.

(Read 12th April, 1928; issued separately 27th September, 1928.)

In the autumn of 1926 it became necessary for me to find out the temperature of the earth in basements of stone, concrete, asphaltum, wood, and the like.

It occurred to me as to whether the trunk of a living tree has a temperature different from that of the surrounding air. Is the temperature of the heart wood different from that of the half-formed surface timber where growth and respiration are active? Does the translocation of food-materials produce heat? Is this heat (if any is found) neutralised by the ascending soil water?

The changes in the internal temperature of an inanimate object always lag behind those of the air outside, but if one continues recording the daily rise and fall long enough—for twelve months —the temperature of a column of iron or stone will average that of its surrounding air.

The choice of a tree fell on a specimen of *Pinus canariensis* in my garden at "Lalbert," Armadale, Victoria, which grew on a lawn amidst other trees, but whose trunk was surrounded by a dense hedge of Coprosma 6 ft. high and 3 ft. thick, which left inside a space 3 ft. wide where one could walk. The shade of the other trees, the branches above, and this hedge, constituted an effective screen between the sun and the trunk; therefore the sun's rays could not shine directly on to the trunk at any time, and only air of shade temperature could ever reach the trunk, conditions which one usually finds in a forest or wood. The girth of the trunk was 12 feet 6 inches at three feet from the ground on 10/7/26, and a year later had increased by an inch. The old dead corrugated bark is about three inches thick. The spread of the branches above is about 70 feet, and its height is 50 feet.

On 10th July, 1926, I took an auger 5/8 in. diameter and 2 ft. long, and having cut a circular cavity in the dead bark 3 in. diameter just down to the living wood, bored a hole 23 in. long to the centre of the trunk, parallel to the earth, from north to south, at a height of 3 ft. from the soil; also another similar hole at a tangent to the circumference of the living sap wood, so that the thermometer would be totally enclosed, and so that its bulb would be some 4 in. inside from the surface of the dead corky bark, and about 1 in. into the living outside ring. This hole ended 3 in. from the beginning of the core hole, and was at the same level, and was bored from the S.E. to the N.W.

Now when one bores a hole into a living tree, heat is engendered by the act; also the cells of wood around the hole begin to flow with sap, consequently the temperature of the first few days recorded by a thermometer is not normal, until the effects of the friction and injury have faded away.

The holes being prepared, thermometers (fitted with rubber corks) which recorded exactly similar temperatures as did my maximum and minimum thermometer at 53°F., at 60° and at 72°, were inserted—one in each hole. The thermometer for the core hole was wired to a skewer of hard wood, whose outer end protruded 1 in. from the rubber cork, in order to facilitate removal for observation; both corks exactly fitted the holes, and by cutting a niche in the corks one could always pull them out so that the column of mercury was uppermost, and put them back the same way. This enables one to see the position of the column instantly on withdrawal, and to read the temperature accurately, even if the column moves. The whole operation of withdrawal, reading and replacement takes only four to five seconds, after one becomes accustomed to it. The maximum and minimum thermometer was hung 1 in. away from the bark at the spot where the bulb of the bark thermometer was, and over the hole of the core thermometer. It is useless to take the temperature of a tree trunk in one part of a forest unless one records the temperature of the air at the same spot.

The temperatures were taken at sundown, but in the warm weather the minimum was read in the morning, and the maximum in the evening of the same day. In the winter the temperatures in my garden were very similar to those issued daily in the *Argus*, but in the summer the temperatures in the garden were much lower than those of the bureau. Having proceeded thus for about one month, and shown the idea to Professor Ewart, he encouraged me to continue for at least twelve months. With few exceptions, due to absence, the recording of temperatures proceeded daily for twelve months, and to facilitate the summarising of the results they are presented in graph form. From perusal of the results it will be seen that:—

(*a*) The mean annual temperature of the heart wood was 1°F. lower than that of the air.

(*b*) The mean annual temperature of the alburnum was 1·1°F. higher than that of the air.

(*c*) The mean annual temperature of the duramen and alburnum combined was the same as the mean temperature of the air.

Further observations showed that although the trunk was shaded, the average temperature of the alburnum on the north side was one degree higher than that on the south side, and hence the average temperature of the centre of the tree was not more than half a degree lower than the mean of the two sides. This difference I suggest is due to the fact that the average temperature of

the air on the south side of this tree was 1° lower than that on the north side. The flow of heated air in Australia is from the north and the flow of cold air is from the south, though it has also been suggested that the ascending water stream cuts off a small fraction of the external heat of the air from the duramen, which otherwise

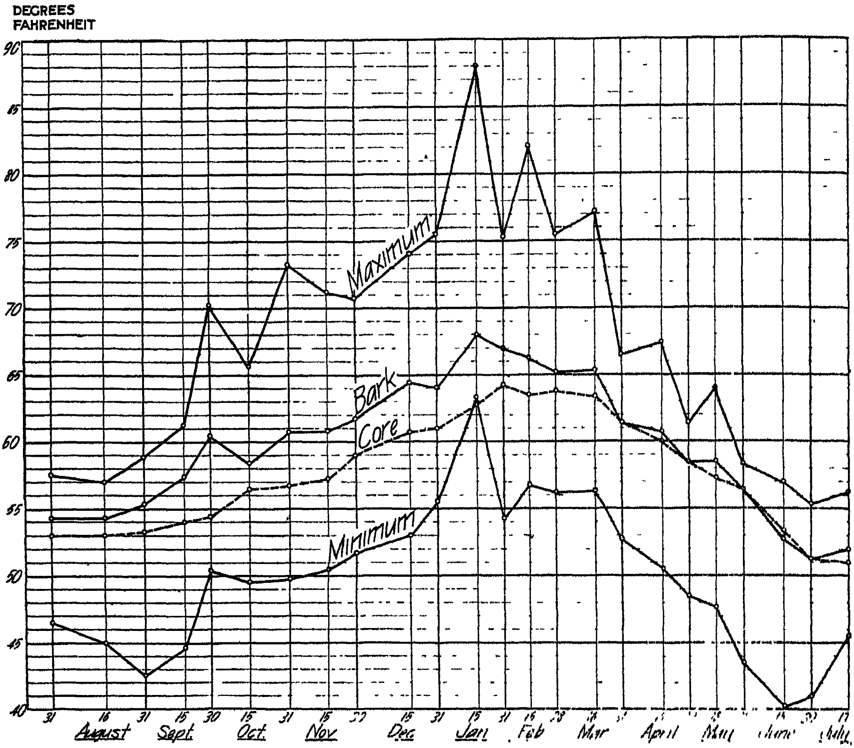

FIG. 1.—Temperature of Air and of a *Pinus canariensis* throughout year 1916-17.
Average mean temperature of air for year 58·7 Fahr.
Average mean temperature of bark and core - 58·7 Fahr.
Trunk 12′-6″ girth at 3′ from ground, completely shaded by dense hedge of Coprosma.

behaves in regard to external temperature variations as an inert mass having no appreciable production of heat of its own.

During the whole period of observation there did not occur at any time any positive indication of any alteration in temperature due to pollination, or the sudden bursting into growth of the needle buds or the growth of branches, nor did sudden drenching with rain produce the fall of temperature one would expect. On March 18th, 1927, the bark on the trunk became soaked with rain, and the temperatures rose 0·5°. This happened again on April 12th, 1927. I suggest this is due to the rushing of the water by

capillarity into the vesicular tissue of dry, dead bark, developing heat by friction and chemical action. The rain was colder than the bark.

As a rule the difference between the maximum and minimum temperatures did not result in much variation in the heat of the alburnum at the time of occurrence in this tree. In June, 1927, owing to a succession of frosts followed by warm afternoons, I took the opportunity of recording the temperature of the alburnum frequently, and from this it will be seen that there was only a difference of 0·5°F. between the temperature at about 6-8 a.m., when the ground was white with frost, and the temperature about 4-6 p.m., when by contrast the air was warm and the afternoon delightfully sunny. I suggest this is due in this tree to the fact that the alburnum is insulated from the air on the outside by a thick layer of dead bark, which is a bad conductor of heat. The slowness of the change in temperature in the core of this tree trunk is illustrated by noting the fact that by the 12th June, 1927, the average daily mean temperature of the air had fallen 7 degrees owing to frost, whereas two feet inside the tree it required four days to reduce the temperature by 2°F.

At the same time I became possessed of the idea that the temperature of this tree was more subject to change from atmospheric causes in the first half of this year than it was in the last half of last year. I suggest it is due to the fact that the tree is drained of water due to its spring growth, and that consequently its specific heat is lower than in the spring.

I have noticed that dead, dry timber seasoned, fluctuates more than timber of the same dimensions does in a living tree, and consider this is due to its low specific heat, owing to the absence of "free" water.[1]

On one occasion the temperature of the core fell faster than that of the alburnum. This was on and about the 21st to the 26th May, 1927, when the temperature of the core was reduced by the falling temperature of the air, would have been the temperature of the alburnum, but for the fact that again rain drenched the bark, and either its condensation in the dead bark or the fact that it was warmer than the air, caused a rise in temperature, which warmed the alburnum. As soon as the rain stopped the bark dried and the temperature of the outside of the tree suffered a quick fall, and on the 26th became lower than the core.

While taking these temperatures daily, I began to take the temperature of many other varieties of trees and their parts, and noticed many curious happenings which may be of interest. This has resulted in the conviction in my mind—

(1) That all dicotyledonous trees average (over long periods) almost the same temperature as the air of the forest or

1 It has been suggested by Professor Ewart, however, that it is due to the effect of the transpiration current.

locality where they live, although small trees have a greater daily variation of temperature than large trees, as they have more bark surface per unit of mass than the latter.

(2) That trees with smooth bark have a greater daily variation in temperature than those with thick, corky, or stringy bark.

(3) That the parts of trees upon which the sun shines have a greater variation than those in permanent shade, and that the thinner branches have a greater daily variation than the trunk.

(4) That the twigs from which the leaves grow vary in temperature hourly.

(5) That the temperature of the smooth barked part of a branch on eucalypts varies more than that of the part which—although the same thickness—is nearer the trunk, and which is covered with stringy or hairy or corrugated bark.

(6) That the average temperature of any part of the trunk of a large tree shows no evidence of any material average difference in temperature from that of the atmosphere. There is always the "lag," but the temperature average is practically the same over long periods.

(7) That all leaves in my garden, whether of Australian or other origin, which admit of the bulb of a thermometer being wrapped up in them, are of the same temperature as that of the air with which they are surrounded.

(8) That the ascending water current can only influence the temperature of the trunk in the alburnum or water-conducting wood.

In conclusion I wish to thank Dr. Ewart for his assistance and for codifying my results; also Messrs. Lang and Mitchell, consulting engineers, for the preparation of the graph.

Temperature of Core and living sap cells of Pinus Canariensis.

NOTE—All tree temperatures were taken at sundown.

1926		Tree Temperatures Core	Tree Temperatures Bark	Air Shade Temperatures Max.	Air Shade Temperatures Min.	Remarks.
July	10	54 °F	54 °	58 °	43 °	Auger heat
	11	53	54	61	50	
	12	53	54	61	49	
	13	53	54	58	44	
	14	53	54	58	48	
	15	54	54	53	45	
	16	53	54	54	42	
	17	53	54	55	45	
	18	53	54	56	43	
	19	53	54	55	40	
	20	53	54	59	48	
	22	53	54.5	69	56	
	23	53	54.5	57	47	
	24	53	54	53	44	Rain
	25	53	54	53	43	Rain
	26	53	54	56	47	
	27	53	54	59	48	
	28	53	54	58	50	
	29	53	54	59	49	
	30	53	54	57	48	
	31	53	54.5	60	50	
Av. 21 days		53	54.1	57.5	46.6	Mean air temp. 52 °
August	1	53	54	55	45	
	2	53	54	59	42	
	3	53	54	53	46	
	4	53	54	55	40	Rain
	5	53	54	56	42	
	6	53	54	55	44	
	7	53	54	55	45	
	8	53	54	56	44	
	9	53	54	54	44	
	10	53	54	65	53	
	11	53	54	60	52	
	12	53	54	58	52	
	13	53	54	56	41	
	14	53	54.5	59	41	
	15	53	54.5	59	48	
	16	53	54.5	57	41	
Av. 16 days		53	54.1	57	45	Mean=51 °
	17	53	54.5	59	48	Buds loosening
	18	53	54.5	66	44	
	19	53	55	65	53	
	20	53	55	53	42	
	21	53	55	52	36	Pollen cones forming
	22	53	55	57	32	Frosty
	23	53	55	61	34	
	24	53.5	55	62	42	
	25	53.5	55	55	53	
	26	53.5	55	54	40	
	27	53.5	55	53	41	
	28	54	55.5	65	34	
	29	54	56	64	49	
	30	54	56	57	47	
	31	54	56	58	42	
Av. 15 days		53.4	55.2	58.7	42.5	Mean=50.6 °

1926		Core	Bark	Max.	Min.	Remarks.
September	1	54	56	63	44	
	2	54	56	63	42	
	3	54	56.5	61	50	Buds bursting freely
	4	54	56.5	59	42	
	5	54	57	56	45	
	6	54	57	57	39	
	7	54	57	60	45	
	8	54	57	67	37	
	9	54	57	72	47	
	10	54	58	59	50	
	11	54	58	59	43	Pollen cones ripe
	12	54	58	63	50	Fruit cones appear
	13	54	58.5	64	52	
	14	54	59	55	45	
	15	54	59	61	40	
Av. 15 days		54	57.3	61.2	44.7	Mean=52.9°
	16	54	59	70	40	
	17	54	59.5	67	41	
	18	54	60	70	43	
	19	54	61	78	45	
	20	54	61	76	53	
	21	54	61	73	56	
	22	54	62	85	57	Hot wind
	23	54	63.5	81	63	
	24	54	62.5	57	52	
	25	54.5	61	70	52	Pollen cones empty
	26	55	60	74	54	
	27	55.5	59.5	73	55	
	28	56	58.5	58	51	Rain
	29	56.5	59.5	60	51	
	30	56.5	59	64	42	
Av. 15 days		54.6	60.5	70.4	50.3	Mean=60.3°
October	1	57	59	74	44	
	2	57	60	74	54	
	3	57	61	68	58	Re-bored hole centre
	4	57	59	67	44	
	5	56.5	58.5	61	54	Very wet and windy
	6	57	58	62	50	
	7	56.5	57	59	49	Wet and windy
	8	56.5	56	58	48	
	9	57	57	60	49	
	10	57	58	70	50	
	11	57	59	68	48	Fine, S. W. wind
	12	57	57	60	45	Gales, rain
	13	57	57	65	52	
	14	56	57	75	48	Rain
Av. 14 days		56.8	58.1	65.8	49.5	Mean=57.6°
	16	56	60	80	47	
	17	56	58.5	77	50	Hot
	18	56	60	75	48	,,
	19	56	60.5	74	52	
	20	56	59	70	45	,,
	21	56.5	62	77	52	
	22	56.5	62	76	55	,,
	23	56.5	61	70	55	,,

1926		*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
October	24	56.5	60.5	70	48	,,
	25					,,
	26	57.5	59.5	66	48	Cool
	27	57.5	62.5	79	50	Hot
	28	57.5	63	82	49	
	29	57.5	62.5	75	59	Gales N.W.
	30	57.5	62	63	49	Bleak (rain)
	31	58	60	68	40	,, ,,
Av. 15 days		56.8	60.9	73.4	49.8	Mean=61.6°
November	1	57.5	59	68	55	
	2	57.5	59.5	68	47.5	
	3	57.5	58.5	61	50	Cold, Gale
	4	57.5	57.5	58	45	,, ,, hail
	5	57	56.5	57	48	,, ,, ,,
	6	57	56.5	66	45	,, ,, ,,
	7	57	60	80	47	
	8	57	65	93	55	N.W. gale
	9	57	65.5	89	55	6 p.m.
	10	57	63	70	51	
	11	57	60	66	47	
	12	57.5	65	86	46	Very dry
	13	57.5	63	74	54	
	14	57.5	63	68	54	
	15	58	62	68	55	
Av. 15 days		57.3	60.9	71.4	50.3	Mean=60.8°
	16	58	62	77	49	
	17	58	61	65	45	Gales rainy W.
	18	58.5	59	63	48	Showers passed
	19	59	61	79	47	Dry conditions
	20	59	62.5	84	52	
	21	59	64	76	59	
	22	59	63	69	55	
	23	59	61	63	54	Cold wind S.W
	24	58.5	59.5	62	51	Needles ex-
	25	58.5	59.5	63	53	panding
	26	59	60	65	47	
	27	59.5				
	28	60	67	97	52	Hot, very dry
	29	60	64	66	60	
	30	60	61	63	53	
Av. 15 days		59	61.7	70.8	51.8	Mean=61.3
December	1	60	62	70	54	
	2	60	62	74	48	
	3	60	70	94	53	
	4	60.5	67	78	62	
	5	61	65	70	60	15 points rain
	6	60.5	63	67	51	W. Gale
	7	61	63	74	47	
	8	61	64	78	57	
	9	61.5	66.5	91	56	Leaves small
	10	61	68	64	58	and scanty,
	11	61.5	64	69	48	too dry
	12	61	62	64	52	Fine and cool
	13	61	61.5	61	51	
	14					
	15	61	66	80	45	
Av. 14 days		60.8	64.5	73.8	53	Mean=63.4°

1926	*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
16	61	65	81	62	16 points rain
17	61	63	75	57	Rain
18	61	62	63	56	
19	61	61	63	53	
20	61	63	72	52	
21	61	64	85	54	} 40 points
22	61	63	64	55	
23	60.5	62	67	55	
24	60.5	65	87	45	
25	61	66	92	60	Hot
26	61	68	82	62	
27	61	66	71	59	
28	61	64	75	55	
29	61.5	64	79	56	No dew
30	61.5	64.5	78	53	
31					
Av. 15 days	61	64	75.6	55.6	Mean =65.6°

1927	*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
January 1—5	absent		85	49	For period of 6 days Rain, drizzle
6	62	64.5			
7	62	64	68	60	
8	62	63	72	57	
9	62	65	90	56	
10	62.5	68	94	67	Hot and dry
11	63	71	96	70	
12	63	72	92	67	
13	63.5	71	90	61	Old needles
14	64	74	102	69	dropping freely
Av. 9 days	62.7	68	88	63.4	Mean=75.7°
15	64.5	73.5	80	63	Cool change
16			70	57	
17	65	73	79	55	25 points rain
18	65	69	75	59	
19	65	66	68	51	
20	65	72	88	50	
21	65	62	83	60	
22	64.5	66	80	50	
23					
24	64	67	83	60	
25	63.5	66	77	55	
26	63.5	65	74	40	
27	63.5	64	64	57	
28	63.5	64	67	53	
29	63.5	63	67	49	
30					
31					
Av. 13 days	64.3	67	75.4	54.2	Mean=64.8°
February 1	64	66	82	52	
2	64	69	89	61	
3	64	66	82	54	60 mile gale
4	64	66	78	60	
5	63.5	63	70	55	
6	63	64.5	74	55	
7	63	65	78	57	Premature Autumn

1927		*Core*	*Bark*	*Max*	*Min.*	*Remarks.*
	8	63	64	67	53	No moisture or
	9	63	65	82	48	dew
	10	63	69	93	56	No sap flow,
	11	63.5	70	98	61	heat now felt
	12	63.5	69	91	73	at once thro'
	13					the bark, no
	14	63.5	68	98	55	evaporation
	15	64	66	68	57	to resist heat
Av. 14 days		63.5	66.4	82.1	56.9	Mean=69.5°
	16	63.5	65.5	70	60	
	17	64	66	77	56	
	18	64	66.5	80	62	
	19	63.5	64	75	57	
	20					
	21	63.5	66	77	55	
	22	64	67	80	53	
	23	64	68	82	61	
	24	64	65	77	54	A little rain
	25	64	64	68	52	
	26	63.5	63	65	55	
	27	63.5	64	74	56	
	28	64	64	82	55	
Av. 12 days		63.7	65.2	75.5	56.3	Mean=65.9°
March	1	64	68	97	59	Very hot
	2	64	70	93	71	
	3	63.5	69	83	80	Sudden cold
	4	63.5	66	67	49	change at
	5	63.5	64	65	52	noon
	6	63.5	62	58	51	
	7	63.5	63	76	48	
	8	63.5	63.5	75	50	
	9	63.5	65	77	48	
	10	63.5	66	84	50	
	11	63.5	68	92	63	
	12	63.5	66	84	58	Lawns nearly
	13	63.5	65	80	51	dead, 160
	14	63.5	64	69	58	points since
	15	63	64	67	58	January 1
	16	63	63	68	57	
Av. 16 days		63.5	65.4	77.2	56.4	Mean=66.8°
	17	63	63.5	72	57	
	18	63	64	62	56	Rain at last
	19	63	63	63	54	Trunk of tree soaking, yet temp. of outer
	20	63	62	63	52	rings rose 0.5°
	21	62.5	61	65	56	F. 70 pts. rain
	22	62	60.5	56	51	Drizzle
	23	62	60	57	54	
	24	61.5	60	57	54	
	25	61.5	60.5	69	57	
	26	61	60.5	65	52	
	27	60.5	60	60	54	
	28	60	60	70	53	
	29	60	61	77	41	
	30	60	62	83	47	
	31	60	61.5	77	55	
Av. 15 days		61.5	61.3	66.4	52.8	Mean=59.6°

1927		Core	Bark	Max.	Min.	Remarks.
April	1	59.5	61.5	69	57	
	2	59.5	60.5	65	56	
	3			85	49	Max. and min. for two days
	4					
	5	60	63	75	52	
	6	60	62	62	46	
	7	60	62	65	53	
	8	60	61	65	55	
	9	60	60	66	44	
	10	60	60	64	51	
	11	60	59	61	44	
	12	60	62	69	49	A little rain
	13	60	60	65	53	
	14	60	59.5	64	51	
	15	60	59.5			
Av. 13 days		60	60.8	67.3	50.7	Mean = 59.0°
	16	59.5	59			
	17	59.5	59	68	43	Max. and min. for two days
	18	59.5	59			
	19	59	59.5	63	50	
	20	59	59	60	45	Hole in bark closing up, re-bored
	21	59	58	58	51	
	22	59	57	59	47	
	23	58.5	57.5	61	52	
	24	58.5	58	62	54	
	25	58	58	60	53	
	26	58	57	58	50	
	27	58	57.5	63	48	
	28	58	60	68	43	
	29	58	60.5	70	47	Many trees dying, leaves falling
	30	58	59	63	48	
Av. 15 days		58.7	58.5	62.5	48.5	Mean = 55.5°
May	1	58	58	57	42	
	2	58	59.5	63	44	
	3	58	59	61	46	Nice rain 30 points. Copious condensation of moisture on thermometer in core lately. This has not occurred before. None on the thermometer in bark
	4	58	58	58	47	
	5	57.5	57.5	62	46	
	6	57.5	57	63	43	
	7	57	58	67	41	
	8	57	60	73	50	
	9	57	59.5	73	48	
	10	57	60.5	67	58	Rain
	11	57	58.5	60	48	Rain, 50 points
	12	57	58.5	57	45	Dull
	13	57	58.5	62	48	
	14	57	58.5	66	49	
	15	57	59	67	54	
	16	57	58.5	68	54	
Av. 16 days		57.4	58.6	64	47.7	Mean = 55.8°
	17	57	59	66	49	
	18	57	57	58	44	
	19					
	20					
	21	57	58	63	44	

1927		*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
	22	57	58	64	46	Rain, 25 points
	23	57	58	60	48	
	24	57	57.5	59	46	Rain
	25	56.5	57.5	58	47	Fall of temp. in core not al-
	26	56.5	56	56	44	ways preced-
	27	56	56.5	55	46	ed by fall of
	28	56	55	51	44	temp. in bark
	29	55.5	54	56	41	Rain
	30	55.5	53.5	56	34	Fine, 26 ° on grass, frost
	31	55	53	58	34	Fine, frost
Av. 13 days		56.4	56.4	58.5	43.6	Mean =51.0°
June	1	54.5	53	57	33	Fine, frost
	2	54	53	59	37	,, ,,
	3	54	53	59	33	,, ,,
	4	53.5	54	60	48	Rain
	5	53.5	55	64	55	
	6	53.5	54.5	58	45	
	7	53.5	54	56	44	
	8	53	54	57	47	
	9	53	52.5	50	40	
	10	53	51.5	51	43	Drizzle & rain
	11	53	52	53	45	
	12	53	51.5	56	33	Frost, fine
	13	52.5	52	55	32	,, ,,
	14	52	51.5	58	33	
	15	51.5	51.5	61	35	
Av. 15 days		53.1	52.8	57	40.2	Mean =48.6°
	16	51.5	51	53	33	
	17	51	50.5	55	32	
	18	51	51	57	46	
	19	51.5	51.5	63	50	
	20	51.25	52.5	60	48	
	21	51.5	52	52	44	Record num-
	22	51.5	52.5	56	46	ber of frosts.
	23	51.5	53	57	49	
	24	51.5	53	57	46	
	25	51.5	52.5	54	47	
	26	51.5	51.5	54	42	Fine
	27	51.5	51	53	37	,,
	28	51.5	48.5	47	31	Fine, very cold fog at 8 a.m.
	29	51.5	49.5	55	32	Fine, warmer
	30	51.5	50.5	57	32	
Av. 15 days		51.4	51.4	55.3	41	Mean =48.1°
July	1	51	52	57	47	It took 4 days for the succes-
	2	51	52	56	45	sive waves of
	3	51	52	57	48	cold to affect
	4	51	52	56	46	the core
	5	51	52	57	49	Rain all over
	6	51	53	59	50	Vic. 50 to 100
	7	51	53	54	44	points
	8	51	52	53	41	
	9	51	51.5	53	42	
	10	51	51.5	58	44	
	11	51	52	58	47	
Av. 11 days		51	52	56.2	45.7	Mean =50.9°

Summary of Average Temperatures.

		Tree		Air		Tree	Air
		Core	*Bark*	*Max.*	*Min.*	*Mean*	*Mean*
July	10-31	53	54.1	57.5	46.6	53.5	52
August	1-16	53	54.1	57	45	53.5	51
	17-31	53.4	55.2	58.7	42.5	54.3	50.6
Sept.	1-15	54	57.3	61.2	44.7	55.6	52.9
	16-30	54.6	60.5	70.4	50.3	57.5	60.3
October	1-15	56.8	58.1	65.8	49.5	57.4	57.6
	16-31	56.8	60.9	73.4	49.8	58.8	61.6
Nov.	1-15	57.3	60.9	71.4	50.3	59.1	60.8
	16-30	59	61.7	70.8	51.8	60.3	61.3
Dec.	1-15	60.8	64.5	73.8	53	62.6	63.4
	16-31	61	64	75.6	55.6	62.5	65.6
Jan.	1-14	62.7	68	88	63.4	65.3	75.7
	15-31	64.3	67	75.4	54.2	65.6	64.8
Feb.	1-15	63.5	66.4	82.1	56.9	64.9	69.5
	16-28	63.7	65.2	75.5	56.3	64.4	65.9
Mar.	1-16	63.5	65.4	77.2	56.4	64.4	66.8
	17-31	61.5	61.3	66.4	52.8	61.4	59.6
Apl.	1-15	60	60.8	67.3	50.7	60.4	59
	16-30	58.7	58.5	62.5	48.5	58.6	55.5
May	1-16	57.4	58.6	64	47.7	58	55.8
	17-31	56.4	56.4	58.5	43.6	56.4	51
June	1-15	53.1	52.8	57	40.2	52.9	48.6
	16-30	51.4	51.4	55.3	41	51.4	48.1
July	1-11	51	52	56.2	45.7	51.5	50.9
Average		57.7	59.8	67.5	49.8	58.7	58.7
		58.7		58.6		58.7	

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ART. III.—*Some Trematode Parasites on the Gills of Victorian Fishes.*

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(With Plates VIII.-XI.)

[Read 12th April, 1928; issued separately 27th September, 1928.]

This work was carried out under the guidance of Dr. O. W. Tiegs, and my thanks are due to him for his assistance and interest.

Methods.—The material was fixed in 1% formalin. Bouin, Zenker, and corrosive sublimate were also tried, but the formalin proved most satisfactory. Iron haematoxylin was used for all sections, and Erhlich's haematoxylin for whole specimens. In cases where the iron haematoxylin overstained the vitellaria in sections, Erhlich was used as an alternative.

Genus **Anchylodiscus** Johnston and Tiegs, 1922.

ANCHYLODISCUS GADOPSIS, n. sp.

(Plate VIII., Fig. 1; Pl. X., Fig. 6.)

Found in great numbers on the gills of *Gadopsis* sp. (River Black Fish).

Locality.—Campaspe River, Vic.

Formalinised animal measures about 0·36 mm. in length, breadth 0·08 mm.

External Features.—Small body, slightly oval in section, with indication of head at anterior end; at posterior end is a well-marked hooked disc. The hooks are arranged in nine pairs, two consisting of large hooks, the bases of which are slightly bifurcated, and are connected by a single crossbar, while seven consist of minor hooks, one pair of which lies across one of the crossbars. The large hooks are supported by a ring of chitinous material (Pl. VIII., Fig. 1). Immediately in front of the pharynx there are two pairs of eyes, of which the anterior pair is the smaller.

Three pairs of " head organs " are present (Pl. VIII., Fig. 1); the cephalic glands are situated slightly anterior to the eyes.

The " brain " lies between the eyes, and is the only indication of the nervous system.

Alimentary Canal.—The mouth is situated ventrally, and is anterior to the eyes. The pharynx is large, intestine is bilobed

and devoid of caeca and ends blindly towards the posterior end of the body.

Reproductive System.—The testis is slightly elongated, lies dorsal to the ovary (Pl. X., Fig. 6), and extends posterior to it. The vas deferens passes forwards dorsally as a very wide tube, and opens posterior to the pharynx by a chitinous penis, which is a straight-pointed structure (Pl. VIII., Fig. 1).

The ovary is a large median structure, situated about half-way along the length of the animal. The oviduct passes forwards and opens to exterior close to the male opening. There is no vagina The vitelline system is very large, and occupies the larger part of the body. The transverse yolk duct passes across anterior to the ovary and opens into the oviduct.

The egg is enormous, the ripe egg in the oviduct displacing the organs of the body.

Points by which *A. gadopsis* is distinguished from *A. tandani* T. H. Johnston and O. W. Tiegs (8) :—

1. One pair of minor hooks lies across one of the crossbars in a median position (Pl. VIII., Figs. 1, 2).
2. No vesicula seminalis could be determined. The time of the season may account for this.
3. The penis is straight instead of curved.

Genus Squalonchocotyle Cerfontaine, 1898.

SQUALONCHOCOTYLE ANTARCTICA, n. sp.

(Plate IX., Figs, 4, 5; Text-Fig. 1.)

This marine parasite belongs to the sub-family Onchocotylinae Cerfontaine (7), of the family Octocotylidae van Ben et Hesse (3). It is very similar to *S. vulgaris* Cerfontaine (7), and *S. grisea* Cerfontaine (7). Found on the gills of *Mustelus antarcticus.*

Locality.—Port Phillip Bay.

Average length of formalinised animal 10 mm., breadth 1 mm.

External Features (Pl. IX., Fig 4).—Body elongated and flattened dorso-ventrally. At the posterior end is a fixing organ which is composed of a fixing disc with a caudal appendage. On the former are three pairs of large suckers arranged in two parallel rows and each provided with a single large hook. Two smaller, unarmed suckers are present at the extremity of the caudal appendage, and a pair of small minor hooks is situated between them. The body is attached to this organ at the level of the middle pair of large suckers.

Each large hook ends in a small pointed structure which is recurved at right angles, and sharply defined from the main body of the hook by its smaller diameter. The minor hooks are Y-shaped, the three arms being more or less equal, and the base of

the Y ends in a small hook which is recurved so as to point in a direction parallel to the long axis of the hook (Text-fig. 1*a*, 1*b*).

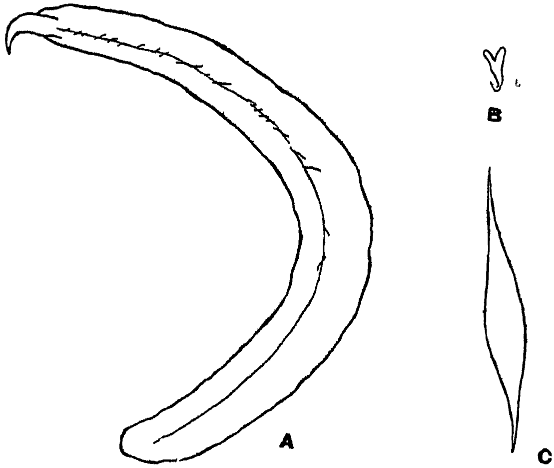

Fig. 1.—*Squalonchocotyle antarctica*, n. sp., drawn with camera lucida. A, major hook; B, minor hook; C, egg.

Alimentary Canal.—The mouth is situated ventrally, and is surrounded by a large circular sucker; a short muscular pharynx opens into the oesophagus, which divides immediately into the two main branches of the intestine. These unite at the posterior end of the body, and pass into the fixing organ. Here the intestine divides again into two single branches passing anteriorly and posteriorly along the disc and caudal appendage respectively. Small unbranched caeca are given off both medially and laterally along the length of the intestine.

Reproductive System (Pl. IX., Fig. 5).—The reproductive organs are typical of the sub-family. The common genital opening is median, and is situated just posterior to the pharynx. The two vaginal openings are lateral, and on nearly the same level as the genital opening.

The eggs are oval and narrow, with two short polar filaments. The length of the egg is approximately 150 μ, which is roughly twice the length of the filaments (Text-fig. 1*c*.).

S. antarctica is distinguished from *S. vulgaris* by the following points:—

1. Shape of buccal sucker.
2. Shape of minor hooks.
3. Length of polar filaments of egg.

S. antarctica is distinguished from *S. grisea* by the following points:—

1. Structure and shape of large hooks.
2. Position of vaginal openings.

Macrophylla, n. gen.

MACROPHYLLA ANTARCTICA, n. gen. et sp.

(Plate X., Figs. 7-9.)

Marine form from the gills of *Mustelus antarcticus*. Found on only two specimens of about a hundred examined.

Locality.—Port Phillip Bay.

Length of formalinised animal 13·15 mm., breadth 1·3-2·5 mm.

External Features (Pl. X., Fig. 7).—At the anterior end on either side is a single pair of large flat expansions, ridged on their ventral surface. Sections of these structures, examined under high magnifications, seem to reveal them as glandular in nature. At the hinder end is a large disc, attached by its middle to the body of the worm (Pl. X., Fig. 7). This disc is provided with a very large sucker, divided by radii into five secondary suckers, of which the largest is incompletely divided into three compartments.

Body Wall (Pl. X., Fig. 9).—This consists, so far as could be made out on the material available, of an epidermis with a marked cuticle. The musculature consists of a circular layer divided into three secondary layers, a well defined longitudinal layer, and vertically running fibres.

Alimentary Canal.—The crescent-shaped mouth opens into an enormous pharynx, which extends well over half the breadth of the animal. The pharynx is extremely muscular, and is provided with large unicellular glands. The intestine is bifurcated, long and narrow, and extends almost to the posterior end of the worm. Along its length numerous branching caeca are developed.

Reproductive System (Pl. X., Fig. 7, 8).—There are two compact testes situated behind the ovary, about a third of the length of the animal from the anterior end. The left testis is situated a little in front of the right. The two vasa deferentia lead into a common tube which travels to the left of and dorsal to the ovary. It then passes forwards almost to the level of the reproductive openings, crosses under the vagina, turns back upon itself and enters the penis. This is a pear-shaped muscular organ, which passes to the exterior along a narrow duct whose opening is situated on the side of the animal just behind the left glandular expansion, and immediately anterior to the uterus.

The ovary is a well-marked, median, round body, considerably larger than the testes. The oviduct passes forwards as a straight tube and continues as the uterus to open just behind the male opening. The vitelline glands extend along either side from the anterior to almost the posterior end of the body. The two longitudinal yolk ducts open into a transverse duct, which runs anterior to the ovary, and opens into a dilated short median yolk-duct, which in turn opens into the oviduct. The vagina has a

common opening to the exterior with the male duct. It passes behind into a curious muscular organ (Pl. X., Fig. 8), which in turn opens into a slightly convoluted tube, leading backwards and emptying into the transverse yolk duct. The muscular organ above referred to, and the proximal part of the convoluted tube which leads away from it, lie suspended in a cavity, indicating that they are distensible structures. It is probable that the tube is a receptaculum seminis, though I have never observed spermatozoa within it.

In two specimens an egg was present in the uterus; it is oval in shape, and measured about 220 μ in length, 107 μ in breadth. The genus *Macrophylla* is distinguished from its nearest ally *Tristomum* by the following points:—

1. Two compact testes as contrasted with numerous testicles.
2. Only five instead of seven distinct radii in posterior sucker.
3. Glandular membranes at anterior end in the place of suckers.

Genus **Octobothrium** Leuckart, 1827.

OCTOBOTHRIUM THYRITES, n. sp.

(Plate XI., Figs. 10-12; Text-Fig. 2.)

Marine form found on gills of *Thyrites atun* (Barracouta).

Locality.—San Remo, Vic.

Length of formalinised animal 7-8 mm., breadth 2-2·5 mm.

External Features (Pl. XI., Figs. 10, 11).—Body elongated and flattened dorso-ventrally, tapering forwards each end; it is more pointed anteriorly. A distinct "head" region is marked off anteriorly by the two lateral openings of the vagina which are surrounded by tumid lips. Posterior end terminates in a fixing disc which is not sharply defined from the body. Disc is provided with eight suckers arranged in two rows converging posteriorly, and each sucker has a complex armature (Pl. XI., Fig. 11, and Text-fig. 2*a*). Two pairs of small hooks are situated at the extreme posterior end, the more anterior pair being the larger (Text-fig. 2*c*). In the "neck" region the body wall is so folded as to give a false appearance of segmentation. (Pl. XI., Fig. 10).

Body Wall.—This consists of a syncytium with a marked cuticle. The musculature consists of a thick layer of well developed longitudinal fibres, the circular fibres being only poorly developed.

Alimentary Canal.—The mouth is situated on the ventral side of the extreme anterior end. On each side of the mouth is a pair of small oral suckers, which is characteristic of the group. The mouth leads into a wide, but not muscular pharynx, opening into the intestine, which forks immediately posterior to the transverse vaginal duct. Numerous diverticula are given off along the whole length of the intestine, both medially and laterally.

Reproductive System (Pl. XI., Fig. 12).—The male organ is represented by numerous testicles occupying the middle of the posterior 3/5ths of the body. The single vas deferens passes up medially and dorsally as a coiled tube, and opens to the exterior on the ventral surface of the "head" by a sucker which is surrounded by small hooks (Pl. XI., Fig. 12, and Text-fig. 2*b*).

The ovary is lobed and single, situated on the right side about 2/5ths of the total length from the anterior end. In stained specimens a lobed structure (Pl. XI., Fig. 10, *y.o*), which takes up the stain very readily, appears in sections to be composed of young ova. There is some doubt about this, as similar stained cells extend from this structure to the posterior end of the body.

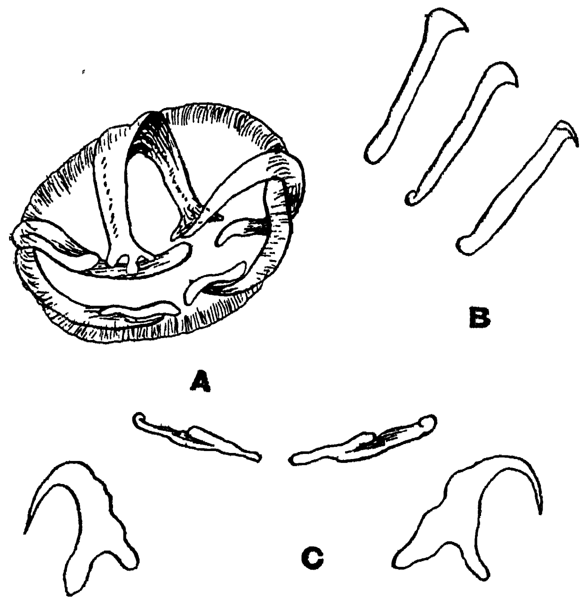

Fig. 2.—*Octobothrium thyrites*, n. sp., drawn with camera lucida. A, armature of posterior sucker; B, hooks of genital apparatus; C, hooks at posterior extremity.

The ovary, however, appears to be continuous with the lobed portion. The oviduct passes forwards dorsally, the shell gland opens into it immediately posterior and dorsal to the yolk reservoir. It continues forwards ventrally as the uterus to open posteriorly to the male genital opening. The vitelline glands extend along either side from the "neck" to the posterior end of the body. The longitudinal ducts open into a large transverse yolk duct which opens medially into the yolk reservoir, to the right of which lies the ovary. A single yolk duct passes down and opens into the oviduct. Laurer's canal is clearly seen as a narrow tube

running from the junction of the oviduct and vitelline duct to the intestine. The two vaginal openings are connected by a single transverse duct, from the centre of which a single duct passes down on the right hand side to open into the double receptaculum seminis (Fig. 12). From this a narrow duct passes down and opens into the transverse yolk duct on the right. By this arrangement, sperm not used in fertilisation may be passed into the intestine. In fact, I have observed in sections structures which closely resemble sperm together with yolk granules in Laurer's canal.

History.—Hermann in 1782 was the first to describe a worm of this group. Then in 1828, Leuckart, and later Kuhn, described the same species. At first the posterior end was taken for the anterior end, and vice-versa.

I have followed Bronn's classification, which gives the following synonyms for *Octobothrium*:—*Dactylocotyle, Choriocotyle, Pterocotyle, Glossoctyle, Octocotyle, Ophiocotyle* and *Octosoma.*

Of the previously described species I have not been able to obtain the literature describing—*O. lanceolatum, O. sagittatum,* and *O. arcuatum.*

O. thyrites is distinguished from *O. thunninae* by the following points:—

1. The arrangement of the suckers on the posterior disc.
2. The posterior disc is not divided from the body by a constriction.
3. The intestine is forked below, not above, the sexual openings.
4. The genital armature is distinctive in both species.

Genus Ancyrocephalus Creplin, 1839.

(Syn. *Diplectanum* Diesing, 1858). (MacCallum 9.)

Ancyrocephalus bassensis, n. sp.

(Plate VIII., Fig. 3.)

Marine form found in great numbers on the gills of *Platycephalus bassensis* (Flathead).

Locality.—Port Phillip Bay.

Length varies considerably; formalinised animal, measuring 0·49 mm. to 0·95 mm.; average breadth 0·09 mm.

External Features.—Body elongate and circular in section. At the anterior end there is a slight indication of a "head" region; at the posterior end is a fixing disc which is not sharply marked off from the body. The disc is armed with nine pairs of hooks, consisting of two large pairs, the bases of which are bifurcated and connected by two cross bars, and seven minor pairs (Pl. VIII., Fig. 3).

Musculature.—This consists of an inner and outer longitudinal layer, with a circular layer between them. The longitudinal layer at the posterior end is strongly developed to supply the disc. Three pairs of head organs and numerous cephalic organs are present, the latter being arranged laterally and extending from the anterior pair of eyes to the region posterior to the pharynx.

Alimentary Canal.—The mouth is situated on the ventral surface in the "head" region, and opens into a very muscular pharynx. This opens into a short oesophagus, passing into the simple forked intestine which ends blindly at the posterior end of the body, and is devoid of caeca.

Reproductive System.—The position of the testis and ovary varies according to the degree of contraction of the animal. The testis is a single large rounded structure taking up the whole of the diameter of the body and lies immediately posterior to the ovary. A single vas deferens is given off anteriorly on the left, and passes forwards ventrally to a large vesicula seminalis, opening to the exterior by a chitinous penis. A well marked prostate gland lies to the left of the penis, into the base of which it opens (Pl. VIII., Fig. 3).

The ovary is much smaller, and lies dorsally and anteriorly to the testis. The oviduct is short, and passes forwards as the uterus to open to the exterior with the vas deferens at the common genital opening which is median and ventral in position. The vagina is very short, and opens on the left just anterior to the ovary; it connects with the receptaculum seminis which is globular in shape, before passing immediately into the genital junction. The vitellaria are well developed, extending along the lateral margins, and the transverse yolk duct passes across anterior to the ovary.

I have found no reference to any other description of this genus occurring on Australian fishes.

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EXPLANATION OF PLATES.

Plate VIII.

Fig. 1.—*Anchylodiscus gadopsis*, n. sp. Entire animal, ventral view.

Fig. 2.—*A. tandani* Johnston and Tiegs. Disc in ventral view (from T. H. Johnston and O. W. Tiegs (8)).

Fig. 3.—*Ancyrocephalus bassensis*, n. sp. Entire animal, ventral view.

Plate IX.

Fig. 4.—*Squalonchocotyle antarctica*, n. sp., Entire animal, ventral view.

Fig. 5.—*S. antarctica*, n. sp. Longitudinal section.

Plate X.

Fig. 6.—*Anchylodiscus gadopsis*, n. sp. Transverse section, showing the relative position of ovary and testis.

Fig. 7.—*Macrophylla antarctica*, n. gen. et sp. Entire animal.

Fig. 8.—*M. antarctica*, n. gen. et sp. Reproductive organs, slightly diagrammatic.

Fig. 9.—*M. antarctica*, n. gen. et sp. Section through body wall, highly magnified.

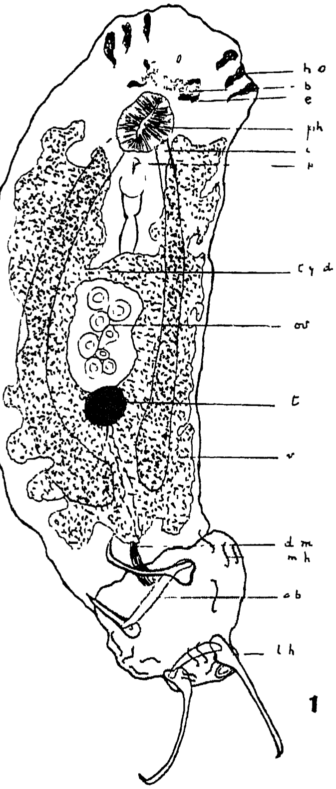
Plate XI.

Fig. 10.—*Octobothrium thyrites*, n. sp. Entire animal with alimentary canal drawn on the right side only, and vitellaria on the left side.

Fig. 11.—*O. thyrites,* n. sp. Posterior end, highly magnified.
Fig. 12.—*O. thyrites,* n. sp. Reproductive organs, slightly diagrammatic.

Explanation of Lettering.

a.s. Sucker with chitinous armature; *b.* "brain"; *b.c.* Buccal sucker; *c.* cuticle; *c.a.* caudal appendage; *c.b.* cross-bar; *c.g.* cephalic glands; *c.g.o.* common genital opening; *c.m.* circular muscle layer; *d.m.* disc muscle; *d.s.* double sucker; *e.* eye; *eg.* egg; *ep.* epidermis; *g.o.* genital openings; *h.o.* "head organ"; *i.* intestine; *i.c.* intestinal caecum; *l.c.* Laurer's Canal; *l.h.* major hook; *l.m.* longitudinal muscle layer; *m.* mouth; *o.* oviduct; *oe.* oesophagus; *o.s.* oral sucker; *ov.* ovary; *p.* penis; *p.g.* prostate gland; *ph.* pharynx; *p.i.* part of intestine; *p.s.* posterior sucker; *r.* radius; *r.s.* receptaculum seminis; *s.* sucker; *s.g.* shell gland; *t.* testis; *t.s.* testicles; *t.y.d.* transverse yolk duct; *u.* uterus; *v.* vitellaria; *v.d.* vas deferens; *vg.* vagina; *vg.o.* vaginal opening; *v.s.* vesicula seminalis; *y.g.* yolk glands; *y.o.* young ova; *y.r.* yolk reservoir.



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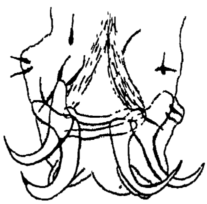

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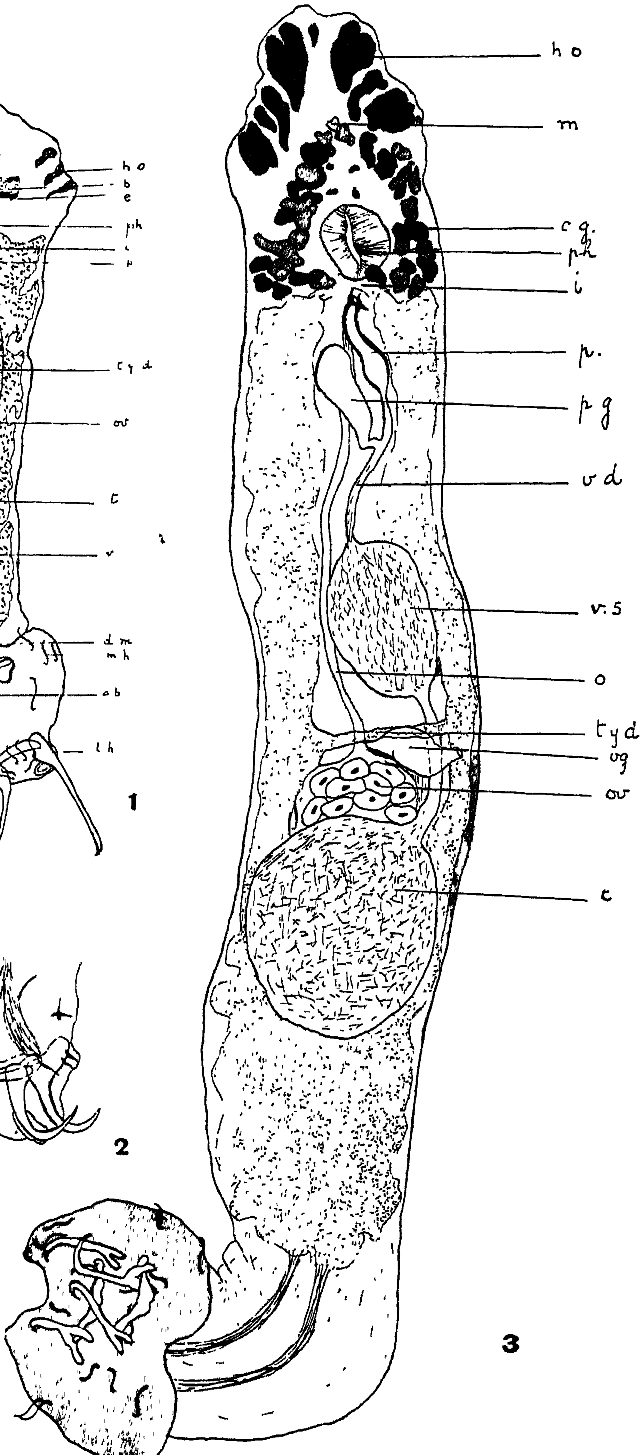

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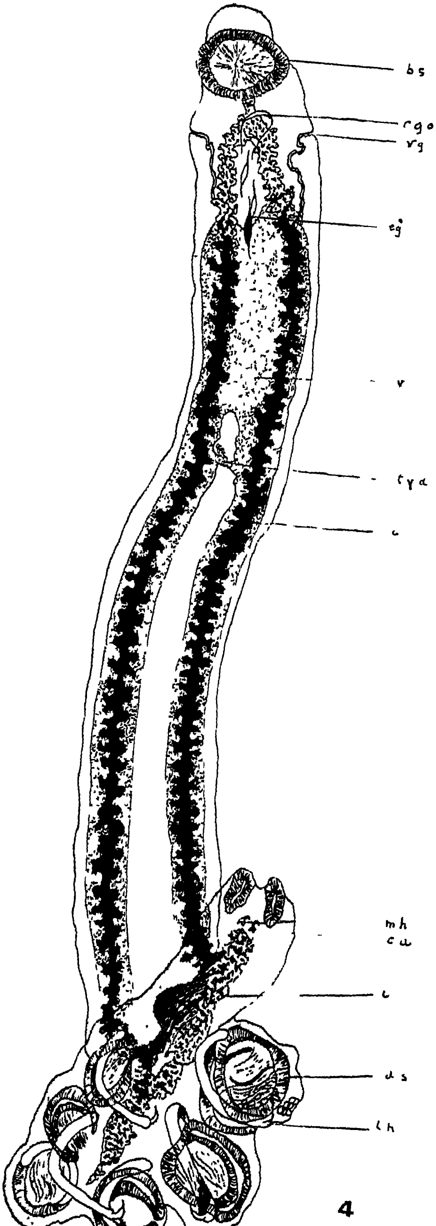

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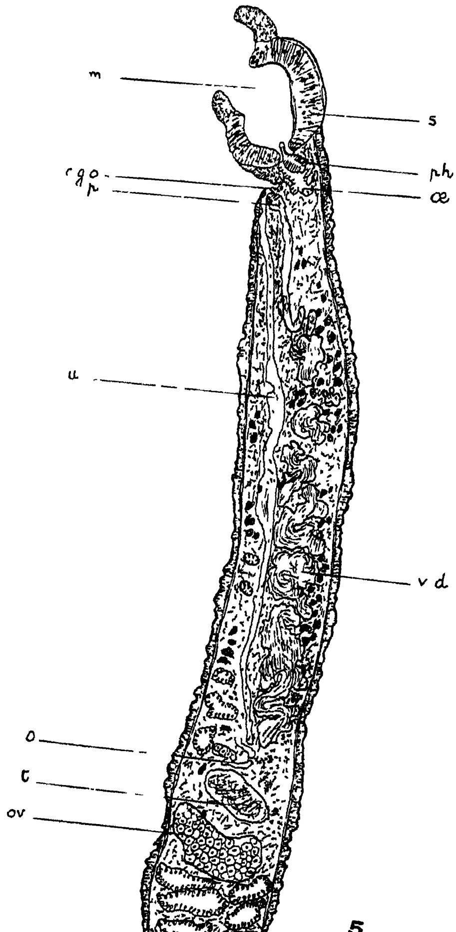

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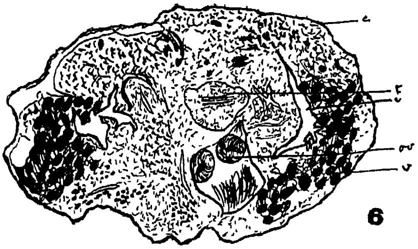
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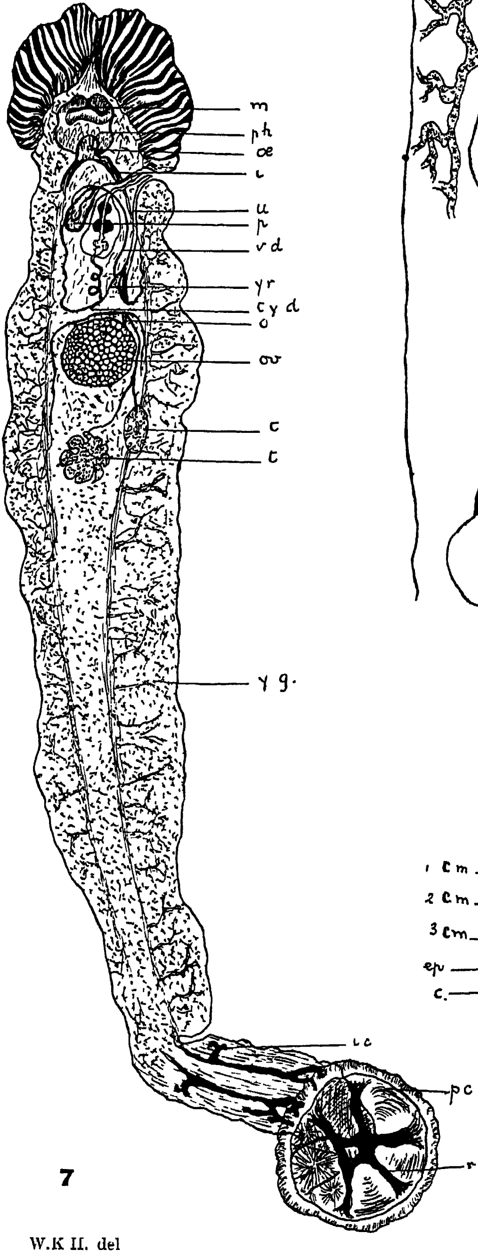
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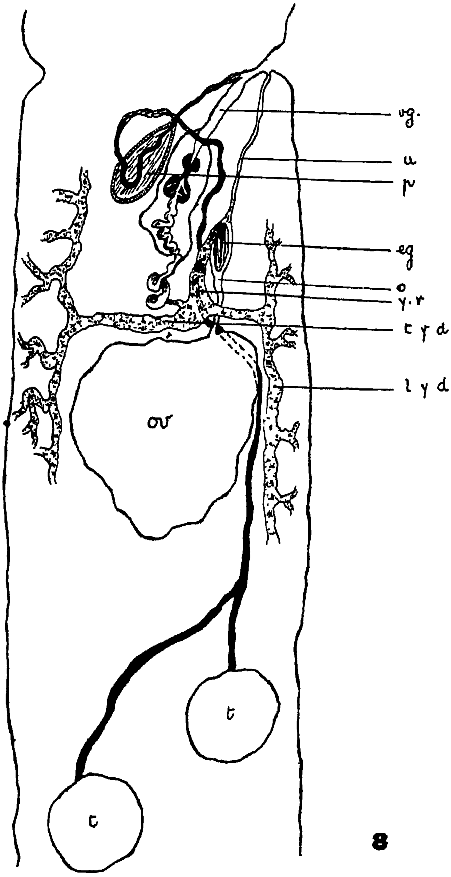
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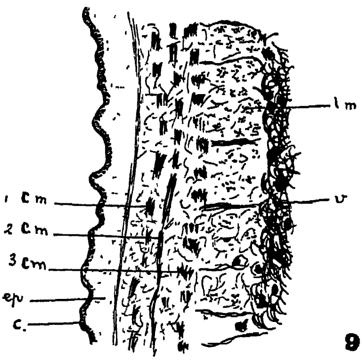
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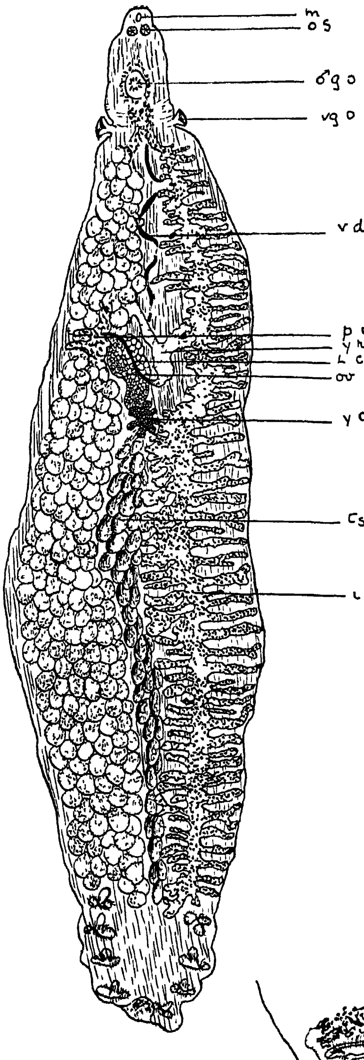

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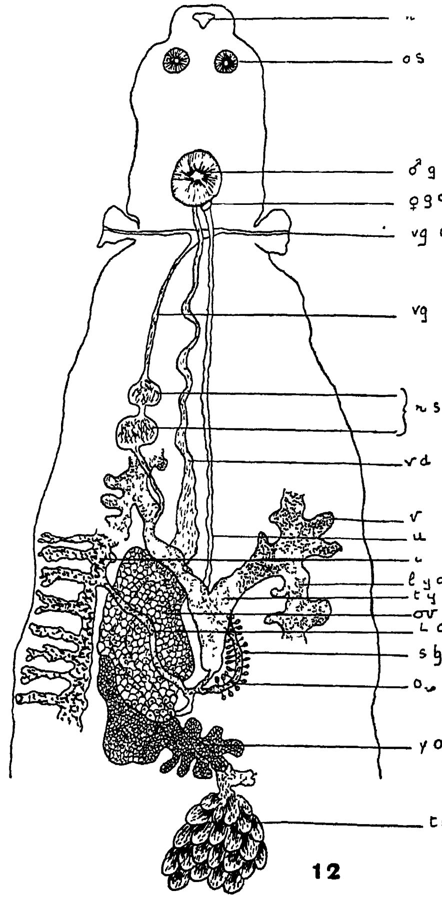

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[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. I., 1928.]

Art. IV.—*Note on the Reflection of X-rays from Glass and Quartz.*

By

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(Read 12th April, 1928; issued separately 27th September, 1928.)

The reflection of X-rays has been observed by the authors for glancing[1] angles up to 45° from glass and 40° from quartz, the critical or limiting angle not having been observed. The X-rays incident on the glass or quartz are, it is believed, heterogeneous X-rays of wave-length in the region of about 50 Å.U. The most intense wave-length in the incident radiation is probably the $K\alpha$ line of carbon of 45 Å.U. wave-length.

That X-rays incident at angles of less than 1° are reflected by glass and by metals is now a well-known phenomenon (1), but that a wave-length of about 50 Å.U. would be reflected when incident at about 40° is not to be expected from the observations already made. Holweck claims to have observed the reflection of long X-rays from polished bronze at 11·7° and 16·2° (2). Dauvillier (3) remarks that he observed in this region (50 Å.U.) optical reflection from glass and from a thin film of melissic acid on lead.

Assuming that we have correctly interpreted the preliminary observations which we have made, it can be concluded that X-rays can be reflected from spherical surfaces and brought to a focus, which will make new methods for the study of long X-rays possible.

Experiments.

The apparatus used in our experiments is a vacuum spectrograph in which the crystal has been replaced by a piece of optically flat plate glass or quartz which acts as the reflector of the X-rays. The target, Wehnelt cathode, the reflector, the camera and photographic film are in the same vaccum.[2] The X-rays

1.—All angles of incidence and reflection stated are glancing angles.
2.—The spectrograph in the use of a common vacuum for the "X-ray tube" and spectrograph is similar to that described by Shearer, *Phil. Mag.*, Oct., 1927.

emitted by the target pass through a circular hole in a shield and then fall on the reflector. The reflected rays pass through a slit into a camera and fall on a Schumann film. Copper and carbon targets have been used. The difference of potential between the cathode and the copper target was at first up to 10,000 volt rectified A.C. In later experiments, the P.D. between the carbon target and the Wehnelt cathode has been about 375 volt given by a battery.

The photographic film on development shows a slit image of the focal spot on the target. This slit image is the same whether it is taken direct, without the glass or quartz reflector, or with the reflector, except that in the latter case there is lateral inversion of the image. The angle of incidence is accurately equal to the angle of reflection. Using the copper target reflection up to an angle of 29° from glass was observed, and with the carbon target rays reflected at 45° from glass and 40° from quartz have been photographed. In each case, this angle is the largest attainable with the spectrometer. An exposure of 1200 milliampere second and a potential difference of 375 volt gives a well-defined image of the focal spot on Schumann film.

Estimates of intensity with the Schumann film are difficult to make. The ratio of intensity of the reflected beam to that of the incident beam in the case of the graphite target is of the order of $\frac{1}{2}$ up to 30° glancing angle. At 40° incidence this ratio had considerably diminished.

The evidence that the radiation is optically reflected appears to be conclusive.

What is the nature of the radiation which is reflected?

As the photographic film is enclosed and placed opposite the slit (0·05 mm. wide) in a metal box which is at the potential of the negative end of the filament of the cathode, the rays cannot be cathode rays.

The radiation—

(*a*) is emitted, as shown by the slit images, from the same focal spot as that from which short wave X-rays[3] were proved to be emitted in other experiments;

(*b*) penetrates aluminium foil[4] 0·0006 mm. thick, about 1% of the incident radiation being transmitted (this foil was tested and found to absorb visible light);

(*c*) is absorbed by glass and by fluorite;

(*d*) is emitted by a carbon target on which 375 volt electrons are incident;

3.—That these rays were X-rays was fully verified by wave-length measurement.

4.—In a previous paper by one of the authors (Shearer, *P. M.* Vol. IV., p. 747, 1927), two thicknesses of aluminium foil were not found to be transparent to X-rays in this region. It should be noted that only one thickness of foil is penetrated in the observation recorded above, and all the conditions in these experiments tend to give an incident beam of increased intensity.

(*e*) is not emitted when the filament is hot, and no potential is applied between it and the anode;

(*f*) is in its action on Schumann film approximately proportional to the exposure measured in milliampere second at constant voltage.

If the radiation is not X-rays emitted according to the usual laws[5] connecting wave-length with applied potential, it can be longer in wave-length than is given by those laws; but it would appear to be very improbable that it is shorter. The observation (*c*) above excludes the assumption that the radiation is in the range of about 8000 down to 1200 Å.U. Observation (*b*) excludes the region longer than 8000 Å.U. It remains to consider the region from about 100 to 1200 Å.U. All the evidence from the observations of Schumann, Lyman, Millikan and Holweck[6] show that radiation in this region is highly absorbed by all forms of matter, and thus (*b*) above excludes the Millikan and Lyman regions of the spectrum. Observation (*e*) confirms that the radiation is not one emitted by a hot body at a temperature up to 1200° C., the highest temperature of the filament. The absorption measurement in (*b*) is consistent with the radiation being of wave-length from 50 to 80 Å.U., assuming the λ^3 law of absorption. Observation (*f*) implies that the radiation is produced by the incidence of electrons on the target.

Taken as a whole, the evidence strongly supports the view that X-rays of wave-length about 45 Å.U. can be reflected at angles up to 40° from glass and quartz.

The Lorentz dispersion formula in the form

$$\delta = 1 - \mu = \frac{e^2}{2\pi m} \sum \left(\frac{n_s}{\nu^2 - \nu_s^2} \right) = 4{\cdot}478.10^{-14} \sum \left(\frac{n_s}{\nu'^2 - \nu_s'^2} \right)$$

where e and m are the charge and mass of the electron, n_s is the number of electrons per unit volume of natural frequency ν_s (wave-number ν'_s) and ν is the frequency of the incident radiation (wave-number ν'), has been shown to give, in the case of X-rays, positive values of δ which are confirmed by experiment (1). Total reflection is therefore to be expected for radiation incident on substances for which μ is less than unity at a glancing angle less than a certain critical value. This was first observed by Compton (1) from surfaces of glass, silver, lacquer and calcite.

5.—These laws have been assumed by Holweck for the range 44 to 300 A.U. "De la Lumière aux Rayons X", Chap. III.

6.—Holweck finds that μ/ρ for celluloid increases rapidly up to about 300 A.U., becomes a maximum at about 320 A.U., and then rapidly decreases toward 1200 A.U.

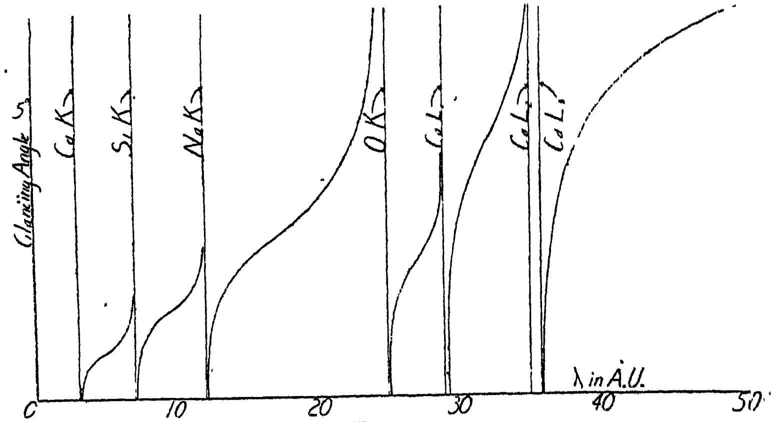

FIG. 1.

In the figure the critical glancing angle for glass θ_c is plotted against wave-length in Å.U. of the incident radiation, where θ_c is obtained from the relation $\cos\theta_c = \mu$ and μ is calculated from the Lorentz formula. n_s is obtained from the following data (assumed):—

Density of glass: 3 gm./cc.
Composition: 71% SiO_2
15% CaO
14% Na_2O.

Number of electrons per atom:

	K	L	M	N
Si(14)	2	8	4	—
Na(11)	2	8	1	—
Ca(20)	2	8	8	2
O(8)	2	6	—	—

The following values of $\lambda_s \left(=\frac{1}{\nu_s}\right)$ in Å.U. were adopted:

	K	L
Si(14)	7	112
Ca(20)	3	33
Na(11)	12	322
O(8)	25	717

The results obtained in this paper do not appear to be reconcilable with this curve.

We have to thank Messrs. H. Massey and C. Mohr for computing the data shown in Fig. 1.

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(2) Holweck. De la Lumiere aux Rayons X, p. 85, Paris, 1927.
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[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. I., 1928.]

ART. V.—*Contributions to the Flora of Australia, No. 35.** *The Naturalized Aliens of Victoria.*

By

ALFRED J. EWART, D.Sc, Ph.D., F.L.S., F.R.S.

[Read 12th July, 1928; issued separately 27th September. 1928.]

These now form a prominent part of the Flora of Victoria, and they are steadily increasing both in numbers of species and of individuals. In 1909 the number of aliens recorded was 363, and in 1928 it had risen to 461. This rate of increase represents approximately one every two months, or slightly more than five a year, and this rate of increase has been maintained with remarkable uniformity during the past sixty years. The alien plants are also more numerous in individuals than the native flora, although the latter represents a much larger number of species, about 3000, and the aliens occupy a greater area of the soil than does the native flora outside of the forest areas.

Nevertheless, all the aliens are not obnoxious, since they include all the clovers, trefoils and medicks, most of the more valuable pasture grasses, and some garden plants that have run wild. Less than a hundred of the aliens are serious weeds, and few of them represent as serious a menace as does our native bracken on newly cleared forest land. In addition, two native plants, the Chinese Scrub (*Cassinia arcuata*) and the Nut Grass (*Cyperus rotundus*), have proved so troublesome as to be proclaimed for the whole State, while the native Prickly Acacia (*A. armata*) has been proclaimed for eleven shires, and the Three-cornered Jack (*Emex australis*) for two.

The sources of origin of the aliens show several points of interest. Naturally most are derived from plants with a wide general distribution. Thus 140 are native to Europe, Asia and Africa, and 66 to Europe and Asia. Of plants native to single continents, Europe has contributed 57 aliens, America 30, North America 18, South America 12, North and Central Africa 11, South Africa 29, and Asia 2. From the Mediterranean region 31 aliens are derived, whereas only 11 are native to Europe, Asia and America, 7 to Europe and Africa, 4 to Europe and America, and 2 to Asia and Africa. Only 8 of our aliens are general cosmopolitans exclusive of Australia, 13 are cosmopolitan to the temperate regions, 7 to the warmer zones, and 2 come from the N. Temperate and Arctic zones.

Not included in the above are the following single cases:—*Avelina Micheli* is derived from Italy, *Calycotome spinosa* from Spain, *Centaurea Picris* from the Caspian region, *Chloris abys-*

*No. 34 in *Proc. Roy. Soc. Vic.*, n.s., xl. (2), p. 81.

sinica from Abyssinia, *Leycesteria formosa* from the Himalayas, *Lychnis divaricata* from Sicily, *Lycium chinense* from China, *Rubus phoenicolasius* from Japan, and *Verbena venosa* from the Argentine. Only one alien, *Eleusine coracana,* has its home in Asia, Africa and America, but several are native to other parts of Australia. *Albizzia lophantha* is native to West Australia and *Andropogon erianthoides* to New South Wales and Queensland, but both have become naturalised in Victoria. *Hibiscus Trionum*, which is native to Europe, Africa, Asia and Australia (with the exception of Victoria and Tasmania), has reached Victoria as an alien with the advent of civilisation, and in the same way *Setaria macrostachya,* which is native to Asia and Tropical Australia, has established itself in the South, aided by man. The activities of man, particularly through the transport of fodder, are probably responsible for the relatively high proportion of aliens contributed by South Africa, and these include some of our worst weeds both here and still more in West Australia (Cape weed, Onion grass, Stinking Roger, etc.).

The native flora of Victoria, exposed as it is to the competition of imported aliens and to the pressure of settlement, is in a condition of rapid flux. It is probable that less than half of the original flora will survive within 50 years, and that many plants originally widely-spread will be confined to special localities. Were it not for the disturbing factors introduced by man the spread of the introduced aliens might have been used as a test of Willis's age and area hypothesis. As it is, although in a very general way the older weeds are more widely spread than the more recent introductions, the rule does not apply to hardly any comparable pair of individual cases. Thus the Evening Primrose, *Oenothera biennis* (1887), has covered less ground than the Foxglove, *Digitalis purpurea* (1917). The Musk Weed, *Myagrum perfoliatum* (1916) has become more abundant than the Horehound, *Marrubium vulgare* (1870), and Onion grass, *Romulea Bulbocodium* (recorded in 1873, but abundant in Melbourne in 1860), with twenty years' start has hardly covered more ground than St. John's Wort, *Hypericum perforatum* (recorded in 1893), but introduced in 1880. A still more striking case is that of the Stinkwort, *Inula graveolens* (1893), which rapidly overtook the Stinkweed, *Gilia squarrosa* (1887), both in area and in abundance.

One would expect the largest number of the naturalised aliens to belong to the Compositae (70), and the disproportionately high number derived from the Leguminosae (50), and from the Gramineae (102) is an aftermath of the pastoral phase when the world was searched for fodder plants to improve our pastures. The native Gramineae comprise 125 species, and many of these are dying out, so that in the near future the grass flora will be mainly foreign. Another curious disproportion is shown among the Monocotyledons. There are 13 alien Irids and only four of the Liliaceae, while no Orchid or Amaryllid has become naturalized,

and only one alien sedge has crept in among the 111 native species of the Cyperaceae. As the native Irideae are only 8 in number, this is the first native order in which the aliens have widely outnumbered the natives. Of the total of 461 naturalized aliens all but twelve belong to natural orders already represented in the flora. The new orders added are Aroidaceae (1), Cactaceae (2), Dipsacaceae (2), Fumariaceae (1), Polemoniaceae (1), Pontederiaceae (1), Resedaceae (2), Salicaceae (1), Valerianaceae (1), but no member of the Myrtaceae, Sapindaceae or Rhamnaceae has become naturalized. Aliens are relatively high in the Labiatae, Solanaceae and Scrophulariaceae, nearly half the latter order being now represented in Victoria by naturalized aliens (24 native species to 18 aliens).

Strictly speaking, the age and area hypothesis is held to apply to closely related plants or to species of the same genus, although if true at all there seems no reason why it should not apply generally or why, if it does not apply generally, it should be true in a restricted form. Even taking species of the same genus, it appears that the time factor is of far less importance in determining the area covered by a species than its suitability to new habitats, its means of distribution, its aggressiveness and its resistance to foes and injurious agencies. In the case of the genus *Poa, P. annua, P. pratensis* and *P. trivialis* were recorded as naturalized in 1878, 1888 and 1888 respectively, but *P. pratensis* has taken the lead because it is better suited generally to the local conditions, and *P. compressa* (1908) is rapidly overtaking some of the earlier introductions. Similarly, in the case of the clovers, taking those which spread by natural means, *Trifolium glomeratum* (1892), is more widely spread than *T. arvense* (1887), and of the red (*T. pratense*), yellow (*T. procumbens*), and white clovers (all 1864), white clover (*T. repens*) has taken the lead mainly because of its superior means of natural distribution and its greater staying power.

According to Willis, however, comparisons cannot be made between single pairs of species, but only between groups of not less than 10 closely related species. As a matter of fact, if the age and area hypothesis has any general value, any average of any 10 pairs selected at random should be as good as two groups of ten each of related species. Even using 10 pairs of related species it is easy to construct natural cases in which the "law" could not apply. Thus, suppose a genus of five species is diverging through subgenera B, C and D, each of five species, and that in groups B and C, the size of the seed diminishes, and in group D that of the pappus, so that groups B and C have twice the rate of dispersal of A and D.

Then, taking any descending order of age for the species groups B and C will occupy double the area relatively to a given age as compared to groups A and D. Beneath the areas are set out proportionately to the ages and rate of spread in each group.

The ages selected are immaterial if they are set out in descending order.

Genus A.	Age in years.	Area in 10,000 acres.	Sub-Genus C.	Age in years.	Area in 10,000 acres.
1	6,000	60	1	2,500	50
2	5,500	55	2	2,000	40
3	5,500	55	3	2,000	40
4	4,500	45	4	1,500	30
5	4.500	45	5	1,000	20
Sub-Genus B.			Sub-Genus D.		
1	3.500	70	1	800	8
2	3.000	60	2	600	6
3	3,000	60	3	600	6
4	2.500	50	4	500	5
5	2.000	40	5	500	5
	Proportion total age to total area	1 : 135		1 : 175	

Hence the proportion between age and area may vary widely even in comparisons between groups of ten, each containing equal numbers of plants with the same rate of dispersal. If groups A and C are compared with groups B and D, the relative proportions between age and area are as 1 : 126 and as 1 : 61.

If groups B, C and D had all twice the rate of dispersal of A, then a simple arithmetical calculation shows that in 6000 years the area of group C and D would become equal to that of group A and B, whereas the average group ages would be as 57 : 100. Suppose that the dispersal of a plant is uniform, so that it spreads at the rate of a mile a year; then the area covered is proportional to the square of the distance of linear dispersal, i.e., to the square of the time, so that in one, two and three years the areas are respectively one, four and nine.

Hence if the groups A, B, C and D all had the same rate of spread and their average ages were 10,000, 5,000, 2,500, and 1,000 years, then the areas covered would be proportional to the squares of the ages, i.e., as (A) 100 : (B) 25 : (C) 9 : (D) 1. Thus the accidental inclusion of a single A plant in a D series because of an apparent close affinity would vitiate subsequent calculations, and to avoid such inclusions it is necessary to assume the age and area hypothesis, i.e., the very thing set out to be proved. It seems probable that the age of a species is one of the least important of the factors governing its distribution, and that in only few cases can a relation be traced between the age of species and the area they cover at the present day. The area of a cosmopolitan is limited by that of the surface of the earth, and during its existence a species like the common bracken or any other cosmopolitan may have travelled several times round the earth. Bracken certainly, and other cosmopolitans probably also, have had sufficient time to cover the surface of a planet far larger than Jupiter, and in such cases the present area of distribution cannot bear any definite relation to the age of the species.

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Art. VI.—*On Grooved, Pitted and Miniature Pedestal Rocks at Lake Goongarrie, Western Australia.*

By J. T. JUTSON, B.Sc., LL.B.

(With Plates XII., XIII.)

[Read 13th September, 1928; issued separately 30th January, 1929.]

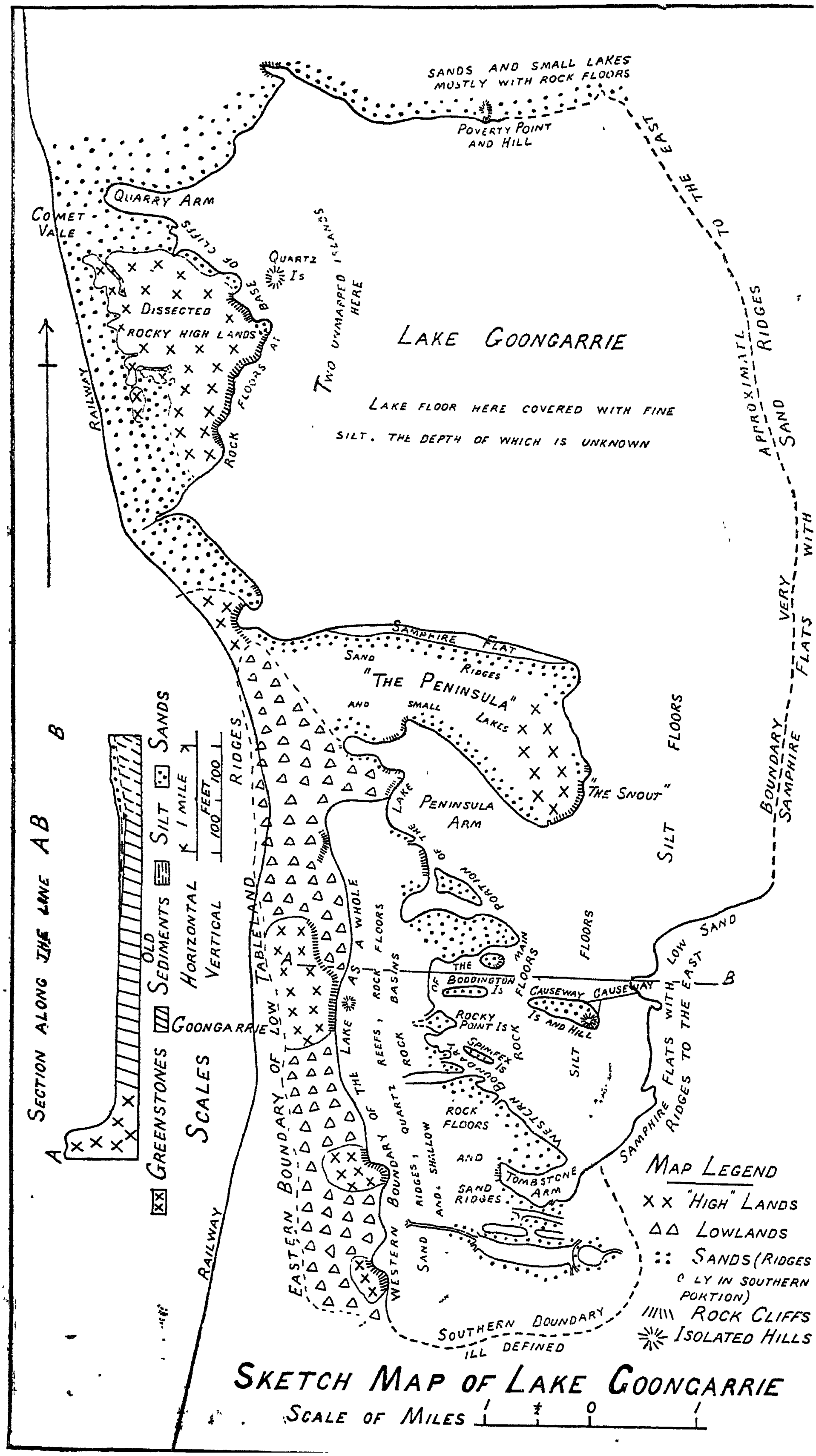
Contents.

I. Introduction.

Lake Goongarrie is a "dry" lake or playa in sub-arid south-central Western Australia. It lies north of Kalgoorlie and just to the east of the railway line from Kalgoorlie to Leonora, and extends northwards from Goongarrie to Comet Vale. It is situated on the Great Plateau of Western Australia, which in the district referred to is about 1200 feet above sea-level.

In the course of geological work some years ago at the mining centres of Goongarrie and Comet Vale, the writer made a sketch survey of the lake, the map of which has been published on a reduced scale in this journal in connection with a paper (1) by the writer on various physiographic phenomena observed during the course of the survey and is here reproduced. The same map, but on a larger scale, appears in an official report (2, Plate I.) by the writer, published by the Geological Survey of Western Australia.

In addition to the phenomena described in the paper (1) just referred to, certain rocks, some *in situ* and some fragmentary, were observed to be pitted, grooved or undermined in a remarkable manner, and under conditions with regard to adjacent rocks



SKETCH MAP OF LAKE GOONGARRIE

that indicated that the forces responsible for the production of such features were working in a peculiarly restricted way. A description of such occurrences, together with a discussion as to the origin of such features, is therefore of interest; but this interest is heightened by the possibility that light may thereby be thrown upon the origin of the surface features of the interior of Western Australia, concerning which—especially in regard to the "dry" lakes or playas—no unanimity has yet been reached. This paper is therefore submitted.

II Previous Literature.

The writer is not aware of any similar phenomena in Western Australia having been described, and he consequently believes that this paper contains the first description of such phenomena occurring in that State, or indeed in any other part of Australia; but the literature of the other States, which may bear on the matter, has not been searched.

Extra-Australian literature treats of some related occurrences, and such will be referred to below.

III. Climatic Conditions.

In order that the facts and arguments submitted may be better appreciated, a brief statement of the climatic conditions of the area is advisable.

The Comet Vale-Goongarrie district has an average rainfall of about ten inches per annum, most of which falls in fairly steady rain during the winter months. In summer, the individual falls are frequently heavier than those of winter, and consequently are probably responsible for more erosion than the winter rains, notwithstanding the greater abundance of the latter. There is great variation in the annual quantity of rain, some years being as low as four or five inches, whilst a wet year may have up to 19 or 20 inches, which, however, is exceptional.

The range of temperature is considerable. In the summer the temperature may frequently rise above 100°F., and in the winter it may fall below 50°F. in the daytime and may reach freezing point at night. In the summer there is great radiation of heat at night, which thus often brings about a pronounced fall in the temperature during that time. The nights are therefore almost always cool.

The humidity is low, but the evaporation of water is enormous, as is shown by the records from Coolgardie, farther south, where the amount reaches 87 inches annually.

Frosts occur in the winter, and hence are responsible for a certain amount of rock splitting. The variation in day and night temperatures also brings about exfoliation of the rocks.

From the writer's observations, the winds, taken as a whole, are not very strong, except the westerlies, which at times blow with great force, and are apparently the dominant winds.

The lake floor is almost always free from water; hence the name "dry" lake. When rain falls it spreads as a sheet a few inches thick over the lake floor, but it rapidly evaporates. This floor is destitute of vegetation, but at its margin, in those places where the ground is but slightly higher, samphire and other salt-loving vegetation grow, whilst the rest of the country carries small trees and shrubs, forming a scrub, with much bare ground between the plants.

IV. Description of the Occurrences.

(A) Grooved Rocks.

(*a*) "*Greenstones.*"—The western side of Lake Goongarrie at Comet Vale consists, in places, of moderately high and steep cliffs of tough, fine-grained basic rocks ("greenstones"), of which amphibolites are probably predominant. At the immediate foot of the cliffs there is a rock floor of similar rocks.

Just south of a large "natural quarry," almost due east of the old Sand Prince Lease,[1] a remarkable set of grooves may be observed in the lowest rocks of the cliff face. These grooves are closely spaced, are usually in straight lines, and run in all directions in a horizontal plane, in that plane in some cases being roughly parallel to and in other cases intersecting one another; but their inclination to that plane is generally vertical or close to the vertical. They may vary from an inch or two to about ten inches in length, with a depth varying from a few lines to about four inches, and a maximum width of an inch. In length, depth and width, the grooves tend to taper into the solid rock.

On careful examination, these rectilinear grooves are found to follow the small irregular divisional planes (due to jointing and earth movements) which abundantly traverse the rocks, but the grooves are not mere openings in the rocks caused by the two sides of a divisional plane becoming forced apart. The rock material has been actually removed by some natural agent so as to leave a distinct groove of the kind indicated. The grooving agent has merely selected the divisional planes as convenient lines for the commencement of operations. Possibly, without such planes the action would not take place, at least not in such a rectilinear fashion. The grooved surfaces are mostly fairly smooth, but they are not polished.

The grooved rocks extend from three to four feet upwards from the lake floor. Above this height grooves are absent, although the rocks form part of the same rock mass as the grooved ones and have the same divisional planes.

1.—This and other leases referred to below are marked on the geological maps accompanying the writer's geological report on the district (2).

Apart from the grooving, the rocks of the cliff face are breaking down under the influence of the weather in the usual way.

The accompanying photograph (Pl. XII., Fig. 1) illustrates the features described.

Grooves in greenstones have also been noted at the following localities, among others:—

(i.) At the large "natural quarry" already referred to, there is a talus of fallen blocks of the fine-grained greenstone, which are grooved for a few feet in height at the base of the talus; whilst the higher blocks are free from grooves.

(ii.) On the western shore of the lake, about four miles north of Goongarrie, at the north-western side of a small "inlet," close to the railway line, grooving occurs in a rock cliff of greenstone, and is there limited to a height of about two feet from the base, where there is also an abundance of fine sand.

(iii.) Grooves occur in fragments of greenstone lying on the surface of the ground at the foot of the cliffs of the same rock to the west of the lake and about a quarter of a mile north of the old Beelzebub Lease, which is situated about one and a half miles to the east of the Goongarrie railway station. The ground here is well above the level of the lake floor. Fine quartz sand occurs in the grooves.

(iv.) A few chains north of the Lady of the Lake Lease, Goongarrie, there are two small greenstone knobs, not exceeding eight feet in height, the surfaces of which largely consist of fragments of the rock, the result of breaking down by the weather. These fragments for a height of not more than two feet from the floor of the knobs are grooved and also pitted. Above this height grooving and pitting do not occur. There is an abundance of fine-grained quartz sand at the bases of the knobs, and also associated with the grooved and pitted rock fragments.

(v.) On the western shore of the lake at Comet Vale, near a small "inlet" just to the north of the old Planet Lease, there is a greenstone knob a few feet in diameter and about eight feet high. The rocks of the knob are grooved to a height of about four feet from the floor of the knob, being higher than usually noticed elsewhere. On the western side of the knob there is a sand dune higher than the knob, which had wind-blown sand scattered around its base and over its flanks to a height of about five feet. At the time of observation the fine sand at the foot of the knob was being rapidly removed by the wind, and blown against the hard rocks of the knob.

(vi.) In the Black Diamond Lease at the southern end of the Goongarrie mining field, a short watercourse, commencing at a high quartz "blow," ends in a small alluvial fan, on the surface of which are many greenstone fragments, mostly a few inches only in length and breadth. On the alluvial fan there is scarcely any vegetation, and the ground is consequently exposed to the full force of the wind. The rock fragments on the fan are grooved

and also pitted. The country rises from the fan, and concurrently the vegetation increases, but as it does so, the rock fragments cease to be grooved and pitted. In the actual channel of the watercourse the rock fragments have neither grooves nor pits.

(vii) On the western shore of the lake, probably at Comet Vale, but the exact locality cannot now be indicated, grooving at the base of the greenstone rocks occurs, and some of the grooves are in parallel lines, being evidently along planes of schistosity in the rocks.

In none of the above instances have the rocks been polished.

In addition to the general grooving of rock masses and irregularly shaped fragments noticed above, an interesting occurrence of grooved rocks may now be described. The phenomena have been observed in one locality only, which is on the western side of the lake at Comet Vale near the grooved rocks first described in this paper.

At this point, on the floor of the lake close to the greenstone cliffs, a number of pebbles of the fine-grained greenstone, possessing distinct horizontal grooves, were observed. The pebbles are numerous, but are confined to a small area. They rest on the lake floor by a fairly flat bottom, but otherwise are generally rounded and usually from one to two inches in diameter. The grooving, practically in all pebbles, commences about a quarter of an inch above the bottom of the pebble, and extends, as a rule, completely around each pebble. The grooves are about half an inch in width, and penetrate the rock to a depth of usually less than a quarter of an inch. The surface of the grooved portions of the rock is even, but only slightly smoother than the surrounding parts of the pebble, and there is no indication of polishing. The pebbles have apparently been quite undisturbed for a considerable time.

(*b*) *Quartz and Jasperoid Rocks.*—At the northern end of Lake Goongarrie there is a prominent hill bordering the lake known as "Poverty Hill" (see text-fig. 1). On account of the toughness of the rocks (quartz in the form of reefs and jasperoid banded rocks, the origin of which has not been investigated) composing this hill, the latter projects somewhat into the lake as a distinct point, and hence this feature is known as "Poverty Point." At the foot of the steep cliff forming Poverty Point there is a flat cone of detritus derived from the rocks of Poverty Hill. This cone rises not more than two feet above the lake floor and in length is about one chain from north to south and two chains from east to west.

Boulders and pebbles of the quartz and jasperoid rocks (of many sizes from an inch to 12 inches approximately) are strewn upon the surface of the cone, and many of them are thin flat-lying fragments. All are more or less rounded and smoothed (but not polished) on their sides and upper surfaces, especially in the case

of the larger fragments. These boulders and pebbles are remarkable for the grooving they have sustained. Some of them have pronounced horizontal grooves completely around them; in others the grooves do not extend so far. Generally speaking, the grooving is much stronger in or entirely limited to those portions which have apparently been particularly exposed to the eroding agents. In the jasperoids, when the bands are not parallel to the surface of the ground, the grooves often follow the bands, and therefore may be at any angle [2] Two horizontal grooves, one above the other, may occur.

The width and depth of the grooves rarely exceed half an inch and are frequently less. The grooves commence usually about a quarter of an inch from the base of the pebbles, but in some cases they were as high as an inch above the base.

In addition to the rounding and grooving, the rocks were also markedly pitted. The pits may be round, elliptical or oval at their mouths and may be drilled at almost any angle from the vertical to the horizontal. In size the pits vary from about two inches to a quarter of an inch or less in diameter. The pits in places unite to form a groove, and, in some instances, the pit has extended into a hole bored right through the pebble.

The grooves and pits and the rounded faces occur, not only in the loose rocks on the small alluvial cone, but also in the rocks forming the base of the cliff. Above a height of about three feet from the floor of the cone, the rocks are almost invariably quite angular, not grooved and not pitted, although some grooving and pitting can be traced to a height of about 25 feet. But where such occurs the cliff is exposed to the action of strong south-westerly, southerly and south-easterly winds.

Similar quartz and jasperoid rocks occur at the Causeway Hill (see text-fig. 1), and there the same phenomena of rounding, grooving and pitting occur as at Poverty Point, to a height, as a rule, of about three feet from the floor of the lake.

At "The Snout" (see text-fig. 1) similar jasperoid rocks are grooved and pitted at the base of the cliff, and also on a shoulder perhaps 20 feet or more above the lake floor, but no details are available.

(B) Pitted Rocks.

(*a*) *Greenstones.*—In various places on the flats, which in part border the western shore of the lake at Goongarrie, there are a number of small, roughly circular knobs of resistant, fairly coarse-grained greenstones, in which felspar and fibrous hornblende are quite prominent. These knobs are usually from about 6 to 15 feet in height, and from about 5 to 12 feet in diameter. The flats on which they rest are usually open spaces,

2.—In the same rocks the evident difference in texture in the component bands brings about differential grooving.

with only a few scattered, low, shrubby plants. The ground may be covered with much white quartz rubble or by sandy or clayey soils.

The rocks of some of the knobs are pitted to a height of about three feet above the surface of the ground. The pits at their openings mostly are circular, with a diameter of usually less than half an inch, and with varying depths, which probably as a rule do not exceed half an inch. The pits penetrate the rocks at different angles, and in places are numerous. They pass alike through the hornblende and felspar, but the hornblende is slightly more resistant to this mode of erosion than the felspar, since in places the hornblende projects as unreduced fragments into the pit, a fact which was not observed in the felspar.

Above the limit in height mentioned, pits are absent, although the upper portions of the rocks are as much exposed to the action of the weather as the lower.[3]

Where pitting occurs, there is generally some fine quartz sand about the base of the knob and in the pits.

It may be noted that in a hornblende felspar porphyry (the precise locality of which cannot now be given) the hornblende was in small spherical nests of about equal size. In the lower portion of the outcrop, the hornblende weathers out more rapidly than the felspar phenocrysts, and hence a number of small pits of uniform size have developed.

The pitting of the greenstones in manner described above may be observed at the following localities:—Towards the northern end of the Bushman Lease, south-east from Goongarrie township; in or near the Lady of the Lake Lease, at the southern end of the Goongarrie field; in the Lord Nelson Lease, just to the west of the Lady of the Lake Lease; and north of the Overlander Lease, which is to the north of the township of Goongarrie.

In addition to the small knobs just referred to, small fragments of greenstone lying on the surface of the ground in certain areas, are also extensively pitted.

The surface of portions of the low-lying, gently-sloping ground, bordering the western shore of the lake at Goongarrie has an abundance of rock fragments of various sizes. The vegetation is sparse, and the fragments, which consist of white quartz and fine and coarse-grained greenstones, are consequently much exposed to wind, sun and rain. It is in the coarse-grained greenstones that pitting, in association with grooving, occurs. Many of the fragments are thin in proportion to their length and breadth, and lie flat. This fact, combined with the gentle slope of the ground, makes the gravitational travelling of the rock fragments very slow; hence many may remain in the same positions for long periods, thus giving erosion an opportunity to make its mark in any particular manner.

3.—A few small pits may be observed on the tops of some greenstone ridges and knobs, but these are clearly due to the action of rain, and they have no relation to the pits of which this paper specially treats.

The pits usually are circular, and may occur on both the top and sides of the rock. On the top, the pits vary in diameter from about one-eighth of an inch to half an inch or more, with similar depths, whilst in some thin fragments the holes have been drilled through from top to bottom. On the sides, the holes do not exceed half an inch in diameter and depth, and are usually much less. Frequently the pits coalesce, and so a more or less continuous horizontal groove may be formed. Fine sand occurs in some of the pits, the surfaces of which are usually fairly smooth.

Localities where the phenomena described may be seen are on the western side of the Golden Sun Lease, Goongarrie; at the small alluvial fan in the Black Diamond Lease, at the southern end of the Goongarrie mining field, referred to under the grooving of greenstones; and generally in various places on the low-lying exposed ground immediately to the west of the lake at both Goongarrie and (more rarely) Comet Vale.

The rocks are nowhere polished.

(*b*) *Quartz and Jasperoid Rocks.*—The pitting of these rocks at Poverty Point and Causeway Hill has been described above when giving details of their grooving.

(*c*) *Other Rocks.*—At the western end of one of the southern arms of the lake, which the writer has named the "Tombstone Arm," a cliff a few feet high occurs, surmounted by a number of projecting but discontinuous rocks of approximately even size. They resemble a number of tombstones, somewhat tilted from the vertical; hence the name, "The Tombstones," given to the locality. These slab-like rocks have had their shape determined by their vertical planes, and by the removal of intervening slabs, but it is not apparent why such a peculiarly selective mode of erosion has taken place.

The component rocks are believed to be fine-grained quartz-porphyries, but the writer's records on this point are incomplete. The surface of a "tombstone" is coated with a film of iron oxide, and is free from pits and grooves.

The rocks which form the low cliff referred to are dark grey shales and slates from which masses several feet in length have been detached. The upper surfaces and sides of these detached blocks often have pits varying in diameter from a quarter of an inch to about one foot, and in depth from a quarter of an inch to three inches. They are usually roughly circular in surface outline, except where two or more pits have coalesced into one elongated one. The pits may be large shallow saucer-like hollows or relatively deep narrow ones, or they may have about the same surface diameter and depth.

At a tiny gully close to "The Tombstones," there is a short, sharp drop to a lower level, down which rain water occasionally falls. The rocks at this point are much pitted, and of especial interest is a concretionary structure which has facilitated the hollowing out of the rocks on vertical faces in a remarkable manner.

The writer's records unfortunately are insufficient to state what these concretionary rocks are.

The shales and slates at "The Tombstones" are mostly free from the iron oxide film mentioned above.

(C) Miniature Pedestal[4] Rocks.

On the western shore of the lake at Comet Vale, and quite close to the rocky cliffs, several examples of miniature pedestal rocks occur. The lake floor at the edge of the lake is a "billiard-table" rock floor. The pedestal rocks are part of the same rock mass as the floor, and consist of fine-grained greenstones of the type already referred to. They are so tough that examples of the pedestal rocks could only be obtained by the writer by wedging them out from the floor along the close-set and irregular joint planes of the rocks.

Kirk Bryan (4, p. 123) describes a pedestal rock as an isolated rock consisting of a larger mass above, supported on a more slender pedestal.

These miniature pedestal rocks attain a height of two to three inches above the rock floor. In horizontal section, the portions above the pedestals are roughly circular or oval, with diameters up to about two inches; and they project about half an inch or more beyond the pedestals, but the extent of the projection varies in the same pedestal rock and in different rocks. The pedestals themselves form short columns about one inch, and less, in height. The result is the well-known mushroom appearance. The surface of the pedestals and of the rock floor overhung by the upper masses is smoothed by abrasion, but is not polished.

At Poverty Point, some of the quartz or jasperoid rock fragments on the surface of the alluvial cone mentioned above, have been undermined so as to form miniature pedestal rocks with a pedestal about an inch in height, and a top that may be six or seven inches in diameter, and which may project one to two inches beyond the pedestal. The rock fragments are smoothed and rounded.

The pedestal rocks described are in miniature only, but nevertheless they are of interest, inasmuch as they indicate, to some extent, the nature of the erosion processes operating in the district.

V. The Origin of the described Phenomena.

For the sake of clearness and convenience of reference, the various types of erosion dealt with in this paper have been separately described. In considering, however, the possible origin of

4.—The word "pedestal" has been suggested by Kirk Bryan (3, 4, and 5) as a descriptive term for the kind of rocks now described, and is preferable, in the writer's opinion, to the old term "mushroom."

the described features, it is convenient to treat the subject as a whole, touching on the various aspects as they arise.

In the following discussion the semi-arid nature of the country, with the resulting scarcity or absence of vegetation, and the abundance of blown sand available must be borne in mind. The mode of occurrence of the sand is described in publications (1) and (6).

As regards the agents of erosion which have brought about the effects noted, the abrasive action of streams, lakes and seas, and of the wind; the action of rain in its mechanical and chemical aspects; the effect of the crystallization of salts at the surface of the rocks; and differential atmospheric weathering generally, must be considered. There may, of course, be a combination of forces.

No satisfactory evidence has yet been adduced to show that the sea has had any influence in moulding the rock cliffs and rock floors of the lake. The former occurrence of large freshwater lakes in the interior of Western Australia has been postulated, but definite evidence is as yet wanting. Even if the sea had recently occupied large areas of the country, or if lakes of the type just mentioned had previously existed, all the effects noted could not be ascribed to such agencies, which may therefore be disregarded.

Again, the erosive power of the very shallow waters that occasionally cover the lake surface is too weak to produce the various kinds of grooving and pitting, or the pedestal rocks described above. Moreover, some of the features observed occur beyond, although close to the lake, so that there must be some agent more general in its action than sea or lake waters.

Rain, chiefly by its chemical action, may form pits in rocks containing much soluble material, such as arenaceous limestones; but such pitting, so far as the writer is aware, is rare in igneous and most sedimentary rocks. Rain, no doubt, in its combined chemical and mechanical action, can groove and pit rocks, but such action would not be limited to a definite height above the surface of the ground. In the examples described in this paper (omitting the rocks at "The Tombstones"), there is such a limitation on the cliff faces, except in occasional special cases, which can be accounted for. Similarly, pitting and grooving are only found among surface rock fragments where the ground is open and largely destitute of vegetation, and therefore exposed to the action of the wind.

Rain, therefore, does not appear to be the primary cause of the pits and grooves, although, once erosion had commenced, it would doubtless be hastened by the rain; but this would hardly or only slightly apply to horizontal pits and grooves.

The effects of the crystallization of salts must be considered. The water beneath the floor of the lake is heavily charged with common salt, and much of the underground water at some distance from the western shore of the lake also contains the same substance in abundance. Other salts also occur.

If crystallization takes place when the water rises by capillary attraction to the surface and there evaporates, the rocks may be disintegrated to some extent, as the writer in an earlier paper (7) has indicated.

Where pronounced divisional planes occur in the face of a cliff (as in the fine-grained greenstone cliffs containing at their base the rectilinear grooves described above) these planes may possibly facilitate the ascension of the salt-charged water through the immediately adjacent areas of the rock; and at the surface, as a result of the crystallization of the salt, slight disintegration or internal strain may occur. If wind-driven sand be the chief cause of the grooves, it would be aided by such disintegration or strain.

The crystallization of salt at Lake Goongarrie cliffs, however, seems to cause an irregular undermining by a flaking of the rock rather than disruption or strain along the divisional planes. Where grooves are several inches deep, it is improbable that they are caused wholly or largely by salt crystallization, as it is difficult to imagine the process working in this regular way. Moreover, the grooved rocks forming the actual cliff face have mostly been broken away from the main mass—apparently before the grooves were formed—and consequently evaporation of the water and precipitation of the included salts would doubtless take place at the surface of the rocks *in situ.*

So far as the writer's observations and recollections go, no disruption or weakening along the division planes occurs. The surface of the grooved rocks is firm, and free from signs of disintegration by flaking or crumbling.

With regard to the pits in the small coarse-grained greenstone knobs, the crystallization of salt may perhaps loosen or detach a mineral fragment, and so be the means of starting a pit; but it is inconceivable that the process should so continue as to form the spherical fairly smooth pits already described. Rather there would be a disintegration over practically the whole of the surface of the area affected. Furthermore, these pitted rocks consist in part of blocks detached from the main mass, and it is a fair assumption that the pits have developed since the detachment—at least in some of the rocks. If so, the crystallization of salts is not likely to occur on the surface of the fragmentary rocks.

With reference to the horizontal grooving of the fragments of quartz, greenstone and other rocks lying loose upon the surface of and, consequently, not in continuous contact with the ground, the same difficulty as to the passage of the capillary water into the fragments again occurs. If, however, this difficulty were overcome, the crystallization of salts at an even height above the surface of the ground seems improbable. Crystallization is more likely to occur over the whole exposed surface. Apart, however, from theoretical considerations, the rock fragments show no evidence of decay through crystallization of salts.

Other chemical action will tend to weaken the coherence of the the rocks, and so make them more easily eroded by any eroding agent.

There is no indication that temperature variation is the cause of the pits and grooves or that it has aided in their formation.

The abrasive action of the wind being the remaining possible factor, is therefore apparently the prime cause of the pits and grooves. Its action is discussed below.

At "The Tombstones" the majority of the pits clearly appear to be due chiefly to the solvent action of rain. This conclusion is suggested by the fact that there is no definite limitation of the height at which they occur, and by the large, shallow, saucer-shaped character of many of the pits. The process appears to start with the formation of small irregular hollows (due to differential atmospheric erosion) on the surfaces of the rocks. Rain water collects in these hollows and acts as a slight solvent, thus further disintegrating the rocks. Further rain will wash out the separated material, and, the processes being repeated, the cavities become enlarged. Some of the smaller pits, and especially the more or less horizontal ones, may be due to the action of the wind. The hollowing out of the rocks at the small waterfall is due mainly to the fall and splash of the water.

Kirk Bryan in various publications (3, 4 and 5) has given instances of pedestal rocks formed otherwise than by wind action. He considers (3, p. 11) their formation to be due to the work of rain, of mechanical disruption, of stream action and of chemical weathering; and he has shown (3 and 5) in lucid and convincing fashion that in arid areas, in some instances, such rocks are moulded into their present shapes by the action of a "drip curtain" during rain, and by the spreading of a film of water on the under surface of the overhanging rock. Pedestal rock formation takes place in this way, especially when a less resistant rock, e.g., a shale, underlies a more resistant one, e.g., a conglomerate. In the case, however, of the miniature pedestal rocks on the floor of Lake Goongarrie, the homogeneous character of the rocks, the smoothness of the face of the pedestal and of the floor forming its base, the absence of the grooves caused by the drip curtain, and the weakness as an eroding agent of such a tiny drip curtain, if formed, suggest strongly that rain action must be eliminated.

The mode of occurrence of the miniature pedestal rocks, where those rocks are *in situ*, should be favourable to erosion by salt crystallization, as it is in undermined areas that one would expect such crystallization to take place. No such effects, however, are visible megascopically. The surface of the pedestal is smooth and free from any indication of crumbling or flaking; and apparently the pedestal is as tough as the rock above and below. If crystallization is taking place, then its action appears to be very slight, or even negligible.

Microscopical examination of the miniature pedestal rocks —as well as of the pitted and grooved rocks—might throw some light on the question whether salt crystallization has directly or indirectly aided in the formation of the pits, grooves and pedestal rocks.

The remarks made above in connection with the pits and grooves as to further chemical action and the effect of temperature variation apply to the miniature pedestal rocks.

The wind in its abrasive capacity therefore appears to be the principal agent in the formation of the pedestal rocks.

By a process of elimination of other possible factors the writer has arrived at the conclusion that the wind in its direct abrasive capacity is the chief agent in the production of most of the unique features described in this paper; and the general conditions prevailing favour this view. These conditions are limitation in height of erosion, which is especially characteristic of wind action; the dry climate; the sparse vegetation; and the abundance of quartz sand. In the case of the pits in the coarse-grained greenstones, Harger's suggestion (7, p. xxxv) with regard to the honeycombing of "augen" gneiss, that the holes were probably started by the weathering out of a particular mineral, would probably apply.

The actual mode in which wind-driven sand brings about the results stated may now be considered, although the subject is a difficult one on account of want of direct observation of the process.

The restriction of the grooves in the cliffs and of the pits in the small coarse-grained greenstone knobs to a height of about three feet above the surface of the ground is probably due—at least in part—to the wind being unable, as a rule, to lift above this height particles of sand of a size or in numbers sufficient to erode a rock surface. This limitation is apparently of wide application. Kirk Bryan (5, p. 12) states that all authorities are agreed that two to three feet above the ground surface is the limit of effective wind scour; and he refers to the paper by W. H. Hobbs, who shows (9, p. 33), among other examples, that in the Great Oasis of the Libyan Desert the cast-iron telegraph poles lining the railway were well burnished by the flying sand to a height above the ground of only about a yard (see also p. 35). Hobbs's observations are strikingly confirmed by the records given in this paper, if wind-driven sand has caused the grooves and pits.

The actual process is difficult to visualize, but the following suggestions are made. The more or less vertical grooves will be first discussed. The sand must be lifted and driven against and perhaps up or down the face of the rocks to the height mentioned. Erosion may take place by this means, but so comparatively evenly —except in specially favourable places—that there is no definite record of the work of the sand blast. The "frosting" evenly over the surface of glass by the sand blast in Nature is an illus-

tration of this widespread erosion. It is easily recognized on the glass on account of the smooth surface of the glass at the commencement of the bombardment of the sand grains, and the resulting roughening of such surface. In rocks, however, such as greenstones, the surface would show little recognizable change, unless the action were very strong, and except, as already noted, in specially favourable places, such as joint or division planes. These provide lines of weakness along which the wind-driven grains may erode faster than the adjacent portions of the rock. In this way a slight groove may be made, which then supplies a definite passage along which the rasping sand grains may be pushed up or down by the wind, which must be assumed, when it approaches the rock face, to be deflected in various ways. So the grooves may deepen, widen and lengthen, and are probably most pronounced close to the ground.

The typical pits on the faces of masses of rock rising well above the surface of the ground are in the coarse-grained greenstone knobs. The formation of the pits in these rocks is no doubt favoured by the comparatively large crystals of felspar and hornblende, of which the rocks are chiefly composed. Bombardment by wind-driven quartz grains, to a height of about three feet above the surface of the ground, takes place, and if, owing to ordinary atmospheric weathering or crystallization of salt, a piece of felspar or hornblende has been detached, a small hollow or incipient pit in the rock face will result. Sand grains are thrown against the rock face to the height mentioned, and some must enter the pit. Centrifugal action as suggested by Harger (8, p. xxxv), may be set up, whereby the sand grains are whirled round the walls of the cavity, thereby increasing its size.

Regarding the horizontal grooving of loose fragments of rocks and to the undermining that takes place in the formation of the miniature pedestal rocks, the grooves usually commence about one-quarter to one-half of an inch above the base of the fragment, although it has been shown in this paper that where bands of varying degrees of toughness occur, and even in apparently quite homogeneous quartz, there may be two horizontal grooves, one above the other. The undermining of the pedestal rock is also just above the surface of the ground. The difficulty is to understand why the groove is formed so uniformly at the height mentioned, and not only in one kind of rock, but also in several classes.

Long and patient work would be necessary to determine this question by actual observation; but if it be accepted, owing to the elimination of all other possible agents as prime factors, that wind-driven sand is the cause, then it must be assumed that such sand, owing to the quantity available, or to its coarseness of grain, or to the strength of the wind itself at the height mentioned, or all or some of these combined, acts most powerfully at that height. The sand must act above this height, but apparently so evenly that it shows no striking effects.

Harger (8, p. xxxiv) states that in late German South-West Africa the cutting or eroding action of the sand-laden blast is the most severe just above the ground level, the heavier grains of sand acting like a rasp and in time cutting upstanding pillars of rock right through, an example in granite being given. Another result is the formation of "mushroom-topped" tors. Harger's observations are thus in accord with those recorded in this paper.

The writer's observations do not show that pits and grooves occur more frequently on one side of an outcrop than on another, except in one or two instances where they are more numerous on the eastern than on the western side.

The dominant winds appear to be westerly, but these may not be the prevailing winds. The wind, however, probably forms eddies in the vicinity of rock masses. See Hobbs (9, pp. 35 et seq.) and Harger (8, p. xxxv), who states that the best and deepest honey-combing is seen on the lee side of the rock masses.

In support of the wind theory, reference may be made to the outcrops of a vertically banded siliceous ironstone about 10 to 12 inches thick, occurring at Goongarrie to the west of the lake. These outcrops form a band at the junction of two other rocks, and they may be traced in a north-north-westerly direction intermittently for some miles. This band projects, on the average, for about 12 inches above the surface of the surrounding ground. Its surface is grooved, pitted, smoothed and rounded, and presents a striking contrast with the sharp contours of similar rocks elsewhere in the district, but situated under different conditions. The bare surrounding ground and the abundance of fine quartz sand in the vicinity leave little doubt that the wind is responsible for the features described.

If the conclusions set out in this paper as to wind erosion, and particularly with regard to the miniature pedestal rocks, be well founded, they are important in that they support the idea that the rock floor of the lake on its western shore is due to wind planation.

The writer has in another publication (10) pointed out that the mode of rounding described in that paper of fine-grained greenstone pebbles does not take place until the iron oxide crust, which is very widespread, has been broken. In the same group of rocks, pitting and grooving do not occur, usually, unless this iron crust is absent. The facts that the fine-grained greenstones from which the crust has always been absent or from which it has been removed after its formation, and that the pitting and grooving of these greenstones occur generally at the base of cliffs, are coincidences merely, since the coarse-grained greenstones and the quartz and jasperoid rocks may be without a distinctive iron crust at any height, but the pitting and grooving are restricted as shown in this paper.

At "The Tombstones," the sedimentary rocks are free from the iron crust, and pits abound in them, but as shown above, they are, in the main, essentially solution hollows. In the adjacent

rocks (probably porphyries), which project well above the surface of the ground as "tombstones," an iron crust is well developed, and pitting is absent. Thus in those two groups of rocks we have striking examples of how erosion may be retarded or hastened according to the occurrence or non occurrence of the protective iron crust.

The relations between the crust-bearing and the crustless rocks, especially those of the same kind, would probably repay close investigation.

VI. Records of Grooving and Pitting elsewhere by Wind Action.

That pitting and grooving of rock surfaces have in some instances has been caused by the action of the wind has been stated by various writers. The following remarks summarize practically all records that have come under the writer's notice. He is indebted to Mr. Kirk Bryan, of the United States Geological Survey, for several of the references.

T. O. Bosworth (11) describes small corrugations and pits in granite, due to erosion by wind-blown sand, on the coast of Mull, Scotland. The quartz and felspar in the rock have been highly polished by this action.

W. P. Blake (12) describes the cutting by the sand blast of a granite surface into "long and perfectly parallel grooves and little furrows" on a mountain pass in California. The rocks were also smoothed and polished by the action of the wind.

R. F. Rand (13) states that at Angra Pequena, on the southwest African coast, biotite schist and granite have suffered great pitting and honeycombing by the action of the wind, which is very powerful and blows from the coast.

A. Wade (14) points out that the softer limestones of the Eastern Desert of Egypt are sometimes regularly grooved by the wind in such a manner as often to simulate bedding planes. Andesites and porphyries are also grooved all over in a peculiar manner by the action of wind-blown sand.

R. D. Oldham (15) describes grooves of varying size in quartzites and sandstones caused by wind erosion.

R. W. G. Hingston (16) records the erosive action of the wind in a gorge in Tibet. Granite boulders on their windward side were polished, and were cut into by deep pits and grooves, some of the latter an inch in depth.

E. de Martonne (17, pp. 663, 664) briefly refers to the disintegration of heterogeneous rocks, such as sandstones, conglomerates and granites. Grains become detached and are swept away by the wind. This results in the formation of a honeycombed surface. The pits may be enlarged by wind corrasion until potholes result, such potholes being common in granites (17, p. 668).

Johannes Walther (18, p. 168 and fig. 132, p. 169) describes the well-known "stone lattice" of the desert.

H. S. Harger (8, p. xxxv and fig. 7) describes the occurrence of "augen" gneiss in the late German south-west Africa, where the rock has been extensively honeycombed by the corrasive action of wind and weather. He points out that the best and deepest honeycombing is seen on the lee side of the rock masses, and that the holes, which were probably started by the weathering away or falling out of a particular mineral, have been rounded and enlarged by loose grit being whirled by the wind around the walls of the cavities.

VII. Summary.

At Lake Goongarrie, a playa in sub-arid Western Australia, the conditions are described under which certain rocks are being grooved and pitted, and others undermined so as to form miniature pedestal rocks.

The rocks concerned are "greenstones," quartz, certain jasperoid rocks, and shales. They occur as rocky cliffs of the lake; as small isolated rocky knobs; and as fragments scattered over portions of the surface of the lake floor on the western shore, and over the adjacent wind-exposed, low-lying ground, which has but scanty vegetation.

These rocks are pitted and grooved. The grooves may run at all angles in a horizontal plane, although in their inclination to that plane tending generally towards the vertical, and, where this occurs, the irregularities are due to the numerous small joints and other division planes by which the rocks are traversed. Other grooves are horizontal. The pits are mostly small, but they are in some cases of moderate size.

Where the rocks occur as cliffs or knobs, the grooving and pitting (except the pits at the locality known as "The Tombstones") are restricted to a height of about three feet from the base of the cliff or of the knob, as the case may be; and where they occur as surface fragments, the grooving and pitting are restricted to those fragments which lie on nearly flat wind-exposed areas with scanty vegetation.

The miniature pedestal rocks are of the fine-grained greenstone class, and occur on the western shore of the lake close to the cliffs of the same rocks, which there bound the lake.

From a consideration of the mode of occurrence of the grooves and pits and of the tiny pedestal rocks, water, both in its mechanical and solvent action, is eliminated as the chief agent in the production of the phenomena described. The disruptive power of salts brought by capillary attraction to the surface, and there crystallizing, is also practically eliminated; and the wind, acting in its abrasive capacity, is regarded as the predominant factor. This, however, does not apply to the pits at "The Tombstones," where

water, in its solvent action, is considered to be the chief cause of those pits.

A brief account of extra-Australian records of pitting and grooving of rocks is given.

The writer is indebted to Professor Skeats for criticism of this paper.

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EXPLANATION OF PLATES.

Plate XII.

Fig. 1.—Rectilinear grooving in the fine-grained greenstone. Cliff face south of the large " natural quarry " on the western shore of Lake Goongarrie at Comet Vale. Note the absence of grooving towards the top of the figure.

Fig. 2.—Miniature pedestal rock of fine-grained greenstone on the floor of the western shore of Lake Goongarrie at Comet Vale, near the large " natural quarry." Slightly less than natural size.

Fig. 3.—Pebbles of the fine-grained greenstone, showing the horizontal groove above the base. From the rock floor of the western shore of Lake Goongarrie at Comet Vale, near the large " natural quarry." Natural size.

Plate XIII.

Fig. 1.—A fragment of the coarse-grained greenstone, showing the almost continuous horizontal groove slightly above the base. Some of the pits on the top can be observed. From west of the Golden Sun Lease, Goongarrie. Natural size.

Fig. 2.—A fragment of quartz with a horizontal groove slightly above the base, particularly shown in profile at each end. From flat cone at the foot of Poverty Point, northern end of Lake Goongarrie, Comet Vale. Natural size.

Fig. 3.—A fragment of jasperoid rock, showing its rounded surface and the deep notch at one end. From near the Lady of the Lake Lease, Goongarrie. Natural size.

ADDENDUM.

A series of papers by the writer treating of various phases of physiography in sub-arid Western Australia appeared in earlier volumes of this Journal. The proofs of most of those papers

Fig. 1

Fig. 2

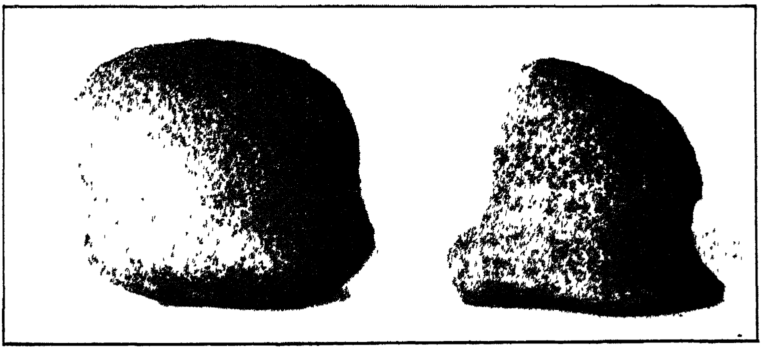


Fig. 3

Fig. 1

Fig. 2

Fig. 3

were not corrected by the writer, with the result that various typographical errors have crept in, which it is now desired to correct, without including all minor palpable errors.

CORRIGENDA.

Proc. Roy. Soc. Vic.

N.S., XXX. (2), 1918.

Page 163, 2nd line: For "water" read "matter."

Page 171, 25th line: For "corrosive" read "corrasive."

N.S., XXXI. (1), 1918.

Page 119, 19th line: For "gravitional" read "gravitational."
26th line: Delete "upon."

Page 121, 3rd line: For "corrosion" read "corrasion."

Page 124, 4th last line of main text: For "corrosion" read "corrasion."

Page 125, 10th line: For "erosinal" read "erosional."
14th line: For "solutions" read "solution."
22nd line: For "corrosive" read "corrasive."

Page 126, 10th last line: For "one" read "once."

Page 128: Add at the end the following:—

EXPANATION OF FIGURES.

Fig. 1.—Locality map of the southern portion of Western Australia.

Fig. 2.—Diagrammatic section showing a piedmont plain truncated at the lake floor. See pp. 117 and 123.

Fig. 3.—Diagrammatic section across an arm (with a sand ridge on either side) of the lake, showing the bare rock floor of the lake and the detritus beneath the sands of the ridges. See pp. 119 and 125-128.

Fig. 4.—Diagrammatic section (after Hobbs) from high land to a playa surface.

Fig. 5.—Diagrammatic section across the lake, showing the lake floor abutting the "high" lands. See page 123.

Fig. 6.—Diagrammatic section across the lake, showing a narrow piedmont plain intervening between the rock floor and the "high" lands. See p. 123.

Pages 113-128: Throughout for "lowlands," read "'low' lands."

N.S., XXXII. (2), 1920.

Page 314, 5th last line: For "38" read "83."

Page 315, 19th line: For "willy-willy," read "willy-willys."

Page 317: The first two sentences under "General Remarks" apply to the first eight records.

Page 319, 3rd last line: For "could" read "would"; and last line, for "hemispheres" read "hemisphere."

Page 320, 20th and 21st lines: The words, "but the rate of motion could not be determined" should be in parentheses.

27th line: Delete the comma after "dull."

Page 321, 12th line: For "columns" read "column."

14th line: For "over" read "ones."

24th line: For "whirls" read "whirl."

Page 322, 2nd last line: For "525" read "52."

[PROC. ROY SOC. VICTORIA, 41 (N.S.), PT II., 1928.]

ART. VII.—*Notes on Australian Termites (Isoptera). Descriptions of new species*

BY GERALD F. HILL.

(With Plate XIV.)

[Read 13th September, 1928; issued separately 30th January, 1929.]

In this paper the following termites are described as new, namely, two species of *Hamitermes* from Western Australia, and one species of *Mirotermes* from each N.W. Australia, N. Queensland and Victoria. The hitherto undescribed alate form of *Eutermes mareebensis* from N. Queensland is described.

The genus *Hamitermes* is widely distributed in Australia, where it is represented by 16 described and numerous undescribed species. Included in the latter are several very striking examples of the sub-genus *Drepanotermes*, which it is considered are best held over until the alate forms have been discovered.

The genus *Mirotermes* is represented by 18 previously described species, which are listed in a recent paper (Hill, 1927). It is of interest to note that one of the species described in the following pages is the first of the genus to be recorded from Victoria.

Eutermes, the third genus referred to in this paper, is represented in Australia by 32 described and probably as many undescribed species, many of which are so closely similar in the soldier caste that the group can be satisfactorily dealt with only in a review of the whole of the available material. The inclusion here of a description of an undescribed caste of a hitherto incompletely known form, however, appears to be justified in view of the fact that the remainder of the writer's collection contains only completely described or wholly undescribed species.

HAMITERMES WESTRALIENSIS, n. sp.

(Plate XIV., Figs. 1, 2.)

Imago.

Colour.—Head very dark brown, slightly darker than pronotum; postclypeus and antennae distinctly lighter; anteclypeus hyaline; legs, labrum and palpi yellow-ochre to ochraceous-tawny; pleurites and sternites mostly yellow-ochre, the former suffused with brown, the latter brown around spiracles; meso- and metathorax and tergites somewhat paler than pronotum; wings dark brown, veins very distinct.

Head.—Hemispherical behind the eyes, depressed angularly in front of fontanelle, a little wider than pronotum, very setaceous, the setae long and short, as on pronotum. Eyes small, prominent (0·192 diam.) surrounded by a pale ring. Ocelli oval (0·096 × 0·144) widely separated (0·128) from eyes. Antennae 16-jointed; 1st joint more than twice as long as 2nd and markedly wider; 2nd a little longer than wide; 3rd very short and closely fused with 4th, which is scarcely longer; 5th about as long as 3rd and 4th together, longer than 6th. Postclypeus markedly setaceous like labrum, with brown median suture, truncate in front, markedly convex behind, strongly arched above, 0·48 long × 0·65 wide. Fontanelle large, about as large as ocelli, oval, with linear extension anteriorly, anterior margin of ovate portion on line with posterior margin of eyes. Anteclypeus hyaline, nearly straight on sides, strongly produced in front.

Thorax.—Pronotum large, nearly straight in front, antero-lateral corners somewhat rounded, sides sloping rather sharply to the slightly sinuate hind margin. Meso- and metanotum narrowed sharply to the deeply notched posterior margin.

Wings (Pl. XIV., Fig. 1).—Large, dark coloured, with distinctly darker veins, the latter distinct to their extremities, the proximal half of the two anteriormost veins markedly setaceous; microtrichia moderately numerous.

Legs.—Moderately long and setaceous.

Abdomen.—Markedly setaceous; cerci with large basal segment, as long as apical segment.

Measurements.

	mm.
Length, with wings - - - - -	14·25 — 14·50
Length, without wings - - -	7·50 — 8·00
Head, from base to apex of labrum, long -	1·60 — 1·67
Head, from base to clypeofrontal suture, long	0·74 — 0·80
Head, at and including eyes, wide - -	1·30
Antennae, long - - - - - -	2·04
Pronotum, long, 0·68; wide - -	1·24
Wings, forewings, long, 12·50; wide -	3·28
Wings, hindwings, long, 12·00; wide -	3·40
Tibia iii, long - - - - -	1·36

Soldier.

Colour.—Head yellow-ochre; thorax, mouth parts (excepting mandibles) and legs light buff; mandibles yellow-ochre at base, shading to dark chestnut towards apex; labrum and clypeus yellow-ochre, margined anteriorly with hyaline, a dark chestnut spot at articulation of mandibles.

Head (Pl. XIV., Fig 2).—Long and very little widened on sides, wide and only slightly rounded behind, strongly arched above; clothed very scantily with reddish setae, these most numerous on the frons. Mandibles relatively short, little more than

half as long as head capsule, stout, strongly curved in at the tips, each with a short tooth a little nearer base than apex. Labrum moderately large, conical, with several stout reddish setae, a little more than half as long as mandibles. Clypeus shorter than labrum, anterior margin strongly bilobed and broadly margined with hyaline. Antennae 15-jointed; 3rd joint very short, much shorter than 1st and 2nd; 4th longer than 5th, about equal to 2nd; gula about one-fourth as wide as head.

Thorax.—Pronotum short and wide, with few long reddish setae, mostly near margins, anterior half narrowed and bent up, with slight emargination, anterolateral angles markedly produced, sides narrowed sharply to obscurely sinuate posterior margin; mesonotum narrower than pronotum, with wide but not deep emargination, fringed with reddish setae; metanotum wider than mesonotum, similarly fringed, posterior margin not so strongly emarginate.

Legs.—Moderately long and slender, with very scanty setae.

Abdomen.—With scanty reddish setae.

Measurements.

	mm.
Total length	5·50 — 6·00
Head, to apex of mandibles, long	2·35 — 2·41
Head, to apex of labrum, long	2·04
Head, to labral suture	1·62
Head, wide	1·36 — 1·42
Head, greatest depth, including gula	1·17
Gula, long	0·32
Pronotum, long 0·50; wide	0·93
Tibia iii, long	1·24

Worker.

Colour.—Warm buff, frons whitish, antennae a little darker than head, mandibles chestnut.

Head.—Posteriorly from the insertion of the antennae hemispherical, with very few setae; postclypeus about one-third wider than long, strongly arched above, anterior margin truncate, posterior margin markedly convex, with scattered reddish setae, a dark ferruginous spot at each end; antennae 16-jointed.

Thorax.—Pronotum as in soldier.

Measurements.

	mm.
Total length	4·50 — 4·90
Head, to apex of labrum, long	1·55
Head, to clypeofrontal suture, long	1·05
Head, wide	1·30
Pronotum, long 0·43; wide	0·86

Locality.—Western Australia; Darlot (Charles Biddle, 6.12.27).

Types (imago, soldier, worker) in the author's collection.

HAMITERMES (DREPANOTERMES) TAMMINENSIS, n. sp.

(Plate XIV., Figs. 3-6.)

Imago.

Colour.—Head, pronotum and principal veins of wings dark brown; antennae and legs light yellowish-brown; pleural sclerites and tergites brown, lighter than head; sternites yellowish, suffused with dark brown at spiracles; postclypeus yellowish-brown suffused with dark brown on sides.

Head (Pl. XIV., Fig. 3).—Clothed with many small setae, widest in front, narrowed slightly posteriorly. Eyes very small and prominent. Ocelli widely separated from eyes. Fontanelle very large, broadly oval. Antennae with 16-17 segments (generally 17); 1st long and stout, cylindrical; 2nd less than half as long and much narrower than 1st, cylindrical; 3rd and 4th very small, closely fused; 5th globose.

Thorax.—Pronotum clothed similarly to head, slightly narrower than head, anterior margin nearly straight, anterolateral angles broadly rounded, the posterior margin broadly rounded with obscure indentation in middle; posterior margin of meso- and metanotum widely notched.

Wings (Pl. XIV., Figs. 4, 5).—Large, all veins very distinct; the two anteriormost veins very setaceous.

Legs.—Long and slender, with numerous small setae.

Abdomen.—Moderately setaceous; setae small.

Measurements.

	mm.
Total length - - - - - -	19·00 — 20·00
Length, without wings - - -	9·00
Head, to apex of labrum, long - -	1·98
Head, to clypeofrontal suture, long - -	1·05
Head, wide - - - - - -	1·60
Antennae, long - - - - -	2·54
Eyes, diam. - - - - -	0·240×0·288
Eyes, from ocelli - - - -	0·160
Eyes, from lower margin of head - -	0·144
Ocelli, longest diam. - - - -	0·160
Pronotum, long 0·93; wide - -	1·48 — 1·55
Wings, forewings, long 16:00: wide -	4·27
Wings, hindwings, long 15·00; wide -	4·52
Tibia iii, long - - - - -	1·86

Soldier.

Colour.—Head, antennae and pronotum dark orange-yellow; legs, tergites of abdomen light clay colour; anterior margin of anteclypeus whitish; labrum lemon-yellow; mandibles mahogany-red.

Head (Pl. XIV., Fig. 6).—Elongate oval, with very few setae; frons rugose; postclypeus strongly bilobed, divided medially by a deep groove; mandibles long and slender, with broad tooth on each about the middle, tooth on left jaw larger than that

on right; gula long and narrow, rather more than one-fourth wider in middle than head. Antennae with 16 (very rarely 17) segments; 1st segment long, moderately wide, twice as long as 2nd, slightly widened towards the apex; 2nd much narrower than 1st, nearly cylindrical; 3rd a little shorter than 2nd, narrow at base but as wide as 2nd at apex; 4th shortest of all; 5th as long as 3rd; 6th-11th lengthening progressively.

Thorax.—Pronotum small, with very few setae, these stout and confined to near the margin except on anterior one-third which bears scattered setae; the anterior one-third narrowed and sharply bent up and rounded on anterior margin; posterior margin rounded, very slightly sinuate in middle. Mesonotum about as wide as pronotum, with sinuate posterior margin and setae as on pronotum; metanotum markedly wider, but not longer, than mesonotum; posterior margin and setae as in the latter.

Legs.—Long and slender, with scanty setae; claws and spines small and slender.

Abdomen.—Short and wide, narrowed abruptly to bluntly pointed apex, with rather scanty, long setae; circi large, the basal segment large, nearly as long as the apical segment, which is slender.

Measurements.

	mm.
Total length - - - - - -	5·90
Head, to apex of mandibles, long - -	2·66 — 2·72
Head, to external articulation of mandibles, long - - - - - -	1·67 — 1·79
Head, wide - - - - - -	1·36 — 1·42
Gula, at narrowest part, 0·031; long -	0·062
Antennae, long - - - - - -	3·28
Pronotum, long 0·62; wide - -	0·93 — 0·99
Tibia iii, long - - - - - -	1·86 — 1·92

Worker.

Colour.—Head, upper surface as in soldier, sides and frons shading to light straw; postclypeus suffused with orange-yellow laterally.

Head.—With very few pale setae, widest in front, narrowed posterior margin; postclypeus about half as long as wide, nearly truncate in front, broadly rounded behind. Antennae with 17 segments; 3rd segment shortest.

Measurements.

	mm.
Total length - - - - -	5·80 — 6·20
Head, to apex of labrum, long - -	1·86
Head, to clypeofrontal suture, long - -	1·17 — 1·24
Head, to external articulation of mandibles, long - - - - -	1·42
Head, wide - - - - -	1·61 — 1·67
Antennae, long - - - - -	2·91
Pronotum, long 0·62 — 0·68; wide - -	0·93 — 1·00
Tibia iii, long - - - - -	1·79

Localities.—Western Australia: Tammin (type locality) all castes, Eradu, soldiers and workers, Merredin, soldiers (J. Clark). Geraldton, queen, soldiers and workers (Edwin Ashby, in January).

Allied Species.—This species is most closely allied to *Hamitermes (Drepanotermes) silvestrii* Hill from Townsville, N.Q., (*Bull. Ent. Res.*, xii. (4), p. 364, 1922), from which the imago is distinguished, *inter alia*, by its much smaller size, darker (less reddish) wings, and fewer antennal segments, and the soldier by its oval, smaller and lighter coloured head and fewer antennal segments.

Types (imago, soldier and worker) in the author's collection.

EUTERMES MAREEBENSIS Hill.

Proc. Linn. Soc. N.S.W., xlvii. (2), 1922.

(Plate XIV., Figs. 7, 8.)

Imago.

Colour.—Head and thorax mummy-brown; tergites of abdomen very little paler; clypeus buckthorn-brown, mandibles (excepting teeth), antennae and trophi a little paler; coxae, trochan-

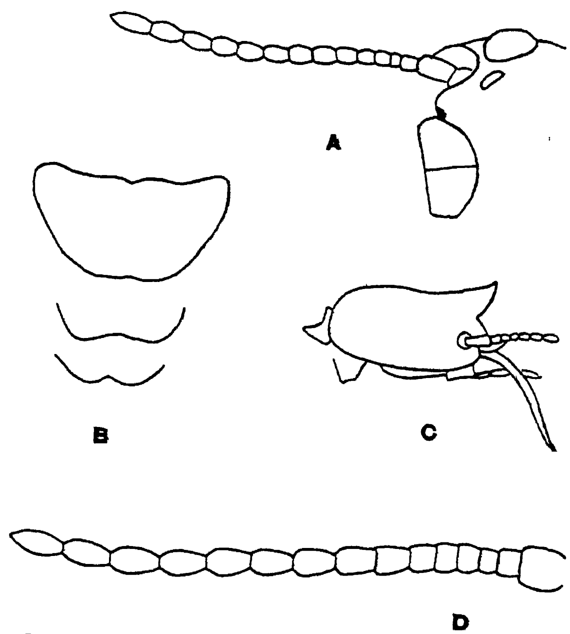


FIG. 1.—*Eutermes mareebensis*, Hill, imago, *a*, head, *b*, thorax. *Mirotermes argutus*, n.sp., *c*, soldier, head. *Mirotermes insitivus*, n.sp., *d*, imago, antennae.

ters, femora and tibiae somewhat lighter than tergites; tarsi whitish, sternites paler than legs, the first four mostly pale yellowish-brown suffused with darker colour laterally; wings smoky, with principal veins same colour as tergites.

Head (Text-fig. 1*a*).—Moderately setaceous, widest in front, almost hemispherical behind the eyes when viewed from above, frontal and transverse sutures distinct. Fontanelle large, linear, nearly as long as eyes are wide, the anterior end slightly widened. Eyes small (0·170×0·170) prominent, about as far from lower margin of head as they are from ocelli. Ocelli large (0·085 long), oval, oblique. Postclypeus large, distinctly lighter than head with a fairly distinct brownish median suture, twice as wide as long, the anterior margin truncate, with a scanty fringe of setae, these mostly longer than the few on the remainder of the postclypeus, posterior margin hemispherical; anteclypeus large, whitish, produced in the middle. Antennae 14-jointed; 1st joint large, cylindrical; 2nd a little more than half as long as 1st and a little narrower; 3rd markedly shorter and narrower than 2nd smallest of all; 4th-13th progressively longer and wider, the 13th nearly as long as 1st; 14th as long as 1st, narrower than 13th, widest at proximal third.

Thorax (Text-fig. 1*b*).—Pronotum moderately setaceous, a little narrower than head, slightly arcuate in front, anterolateral corners, narrow sides sloping sharply to the narrow and slightly sinuate posterior margin; posterior margin of meso- and metanotum more sinuate than in pronotum.

Wings (Pl. XIV., Figs. 7, 8).—Slender, the radial sector and first six or seven branches of the cubitus very distinct, the former and the margin very setaceous. Membrane with rather numerous microtrichia, and densely covered with star-like micrasters. The media passing through the wing a little above the middle, and joining the margin a little above the apex, generally with one branch about the distal fifth to the hind margin; the cubitus with about eleven branches, the first two or three very short, the others not so well-defined, but easily discernible to their extremity, mostly unbranched.

Legs.—Dark coloured, short and comparatively stout; the femora with scanty setae; tibiae with markedly stronger and more numerous setae; tibiae, spurs and claws long and slender.

Abdomen.—

Measurements.

	mm.
Length, with wings ♂ 7·50 — 8·00; ♀ -	8·00 — 8·50
Length, without wings ♂ 4·10 — 4·44; ♀ -	4·67 — 4·90
Head, to apex of labrum, long - -	0·91
Head, to clypeofrontal suture, long - -	0·46
Head, at and including eyes, wide - -	0·69
Antennae, long - - - -	1·10
Pronotum, long 0·34; wide - -	0·60
Forewing, long 6·00 wide - -	1·52
Tibia iii, long - - - - -	0·62 — 0·68

Locality.—North Queensland; Meringa (F. H. Taylor, Nov., 1924).

The identity of the above has been established by comparison of associated soldiers and workers with the types of these castes (from Mareeba, Cairns hinterland, N.Q.).

Types (imago, soldier and worker) in National Museum, Melbourne.

Mirotermes argutus, n. sp.

Soldier.

Colour.—Head, antennae and palpi light orange-yellow, thorax and legs stramineus.

Head (Text-fig. 1*c*).—Long and narrow, parallel on sides, with scanty long setae; frontal process large, stout at base, rather bluntly pointed, the extreme tip bent upwards. Antennae 14-jointed, slender; 1st joint large, more than twice as long as 2nd and one-third wider, slightly swollen at apex; 2nd longer than wide, parallel on the sides; 3rd and 4th smallest, 4th a little smaller than 3rd; 5th-9th increasing in length progressively; 10th-14th subequal, long and narrow (about as long as 8th). Labrum narrow, parallel on the sides, truncate in front with the anterolateral corners produced into points. Mandibles very long and slender. Gula long and narrow, about one-fourth as wide as head.

Thorax.—Pronotum small, much narrower than head, saddle-shaped, anterior margin convex in the middle, the anterolateral corners narrowed, sides and posterior margin together nearly hemispherical, with scanty long setae.

Measurements.

	mm.
Total length - - - - -	4·25
Head, to apex of frontal process, long -	1·42
Head, deep - - - - - -	0·62 — 0·74
Head, wide - - - - - -	0·86
Gula, at narrowest part, wide - -	0·228
Antennae, long - - - - -	1·70
Mandibles, long - - - - -	1·14
Pronotum, long 0·27 — 0·28; wide -	0·56 — 0·57
Tibia iii, long - - - - -	0·62

Worker.

Colour.—Head light orange-yellow, frons whitish, antennae, thorax and legs pale stramineus.

Head.—Glabrous, almost spherical as seen from above, widest at antennae, with scanty setae. Clypeus large, strongly convex, with obscure median suture, a pale ferrugineous mark at articulation of mandibles, with a few setae; anteclypeus large, nearly as long as postclypeus. Labrum small, markedly convex, with few setae. Antennae 14-jointed; 3rd and 4th joints smallest, closely

fused, 5th shorter than 2nd, globular; 6th-14th increasing in length progressively; 14th noticeably longer than 13th, narrowed from the proximal fourth to the pointed apex.

Thorax.—Pronotum, as in soldier.

Measurements.

	mm.
Total length - - - - - -	3·50
Head, to apex of labrum, long - -	0·85
Head, to clypeofrontal suture, long - -	0·60
Head, wide - - - - - -	0·74 — 0·80
Pronotum, long 0·22; wide - - -	0·45
Tibia iii, long - - - - - -	0·60

Locality.—Victoria, Kewell.

Described from a soldier and three workers; found under a log (February).

Allied Species.—The soldier differs from the typical form of *Miro-termes kraepelini* Silv. in having a shorter and narrower head, more angular frontal process, and much more slender mandibles. From variety "A" of the last named species (Hill, *Mem. Nat. Mus., Melb.*, No. 7, 1927, p. 95) it differs in having a more angular and straighter frontal process, longer, shallower and deeper coloured head and different labrum; from variety "C" it differs in its smaller and narrower head, more slender mandibles, narrower and otherwise different labrum; from variety "E" it differs in having a shorter and narrower head, more slender man-dibles, narrower labrum and more slender frontal process.

Types (soldier and worker) and others in National Museum, Melbourne; collected and donated by Mr. Jas. A. Hill, of Mur-toa.

MIROTERMES JARMURANUS, n. sp.

Imago.

Colour.—Head, thorax and tergites of abdomen argus-brown; legs, antennae and sternites of abdomen buckthorn-brown; clypeus ochraceous-tawny. The whole insect densely setaceous, many of the setae markedly long.

Head.—Almost hemispherical when viewed from above, the summit depressed, fontanelle obscured by setae. Eyes moderately small (0·306×0·306) and prominent. Ocelli large (0·170 long) broadly oval, a little less than their short diameter from eyes. Antennae 15-jointed, very long; 3rd joint very large, not much smaller than 1st; 2nd very small, bead-like; 4th and 5th long and narrow, shorter and narrower than 3rd; 6th longer than 4th and 5th; remaining joints very long and narrow. Mandibles each with apical tooth much larger than, and widely separated from, the next. Postclypeus small, strongly convex above, with numerous long and short setae; anteclypeus whitish, short, truncate in front. Labrum small, longer than wide, not covering apex of mandibles.

Thorax.—Pronotum very large, markedly longer than wide, strongly arched, conspicuously concave in front, sides sloping to the broadly rounded posterior margin. Posterior margin of meso- and metanotum narrowed and deeply notched, the metanotum more so than mesonotum.

Wings.—Wing stumps small, those of mesonotum not much larger than those of metanotum.

Legs.—Moderately short and stout; very setaceous.

Measurements.

	mm.
Length, without wings	6·15
Head, to apex of labrum, long	0·96
Head, to clypeofrontal suture, long	0·74
Head, at and including eyes, wide	1·19
Head, deep	0·51
Antennae, long	2·28
Pronotum, long 0·85, wide	1·19
Tibia iii, long	1·19

Locality.—North-West Australia: 130 miles south-east of Broome (July or Aug., 1924).

Described from a dealated female, collected and presented to the National Museum, Melbourne, by A. S. Cudmore.

It is possible that the specimen described above is the macropterous form of *M. broomensis* Mjöb., only the soldiers and workers of which have been described.

Mirotermes insitivus, n. sp.

(Plate XIV., Figs. 9-11.)

Imago.

Colour.—Head very dark brown, postclypeus very little lighter than head, anteclypeus whitish; labrum suffused with yellow; antennae, mouth parts and legs. light brown; pronotum nearly as dark as head; wings dark smoky.

Head (Plate XIV., Fig. 9).—Small, rounded when viewed from above, rather densely clothed with short and long setae. Eyes rather large (0·289×0·289), prominent, close (0·04) to lower margin of head, closer than to ocelli. Ocelli large (0·136), broadly oval, separated from the eyes by a space equal to their short diameter. Postclypeus moderately large, about twice as wide as long, strongly convex, hemispherical behind, truncate in front, with rather distinct median suture and clothed moderately densely with small setae; anteclypeus less than half as long as postclypeus, nearly truncate in front. Labrum small, a little widened in the middle, moderately convex, densely setaceous, broadly rounded in front. Fontanelle small, oval, laying within a small depressed area and in line with the middle of the eyes (in all cleared preparations there is to be seen a dark-coloured, broadly oval posterior extension of the fontanelle).

Antennae (Text-fig. 1*d*).—15-jointed; 1st joint short and wide, two-thirds as wide as long, as long as 14th; 2nd short and wide, as wide as long; 3rd very short, but nearly as wide as 2nd; 4th and 6th about equal to 2nd; 5th wide, but a little shorter than 4th and 6th; 8th to 13th about equal, a little longer than 7th, the latter wider at base than the following joints; 14th, a little longer than 13th, but hardly as long as 15th, which is elongate-oval, and widest in the middle. Mandibles with apical tooth on each side much larger than the next; dentition as shown in (Pl. XIV., Fig. 9).

Thorax.—Pronotum very large, as wide as head, densely setaceous, rather strongly arched, the anterior margin broadly concave, anterolateral angles rounded, sides sloping sharply to the narrow posterior border, the latter sometimes almost truncate, but generally markedly emarginate. Meso- and metanotum with the sides markedly narrowed posteriorly, the hind border of the former generally emarginate as in pronotum, that of the latter much more deeply and acutely notched, both sclerites markedly setaceous, though less setaceous than pronotum.

Wings (Pl. XIV., Figs, 10, 11).—Generally with hindwings a little longer and wider than forewings, rather wide relatively to length, of same colour as those of *M. kraepelini,* very setaceous along border and radial sector; the two anteriormost veins, especially the radial sector, very dark; all the veins distinct to their termination; the media passing through the upper third of the wing, with 4 or 5 branches, the first generally a little beyond the middle and sometimes branched, the main stem joining the margin near the apex of the wing; the cubitus with 8-14 branches, seven or eight nearest the base very dark and distinct. Membrane with few microtrichia, but densely covered with micrasters. Wing-stumps small, very setaceous, suture straight.

Legs.—Densely setaceous, femora a little less so than tibiae; claws and spurs long and slender.

Abdomen.—Very setaceous, the setae shorter and finer than those on head and thorax; circi short and very wide at base.

Measurements.

	mm.
Length, with wings	11·00 — 11·50
Length, without wings	6·00 — 6·50
Head, to apex of labrum, long	1·14
Head, to clypeofrontal suture, long	0·57
Head, at and including eyes, wide	1·14
Antennae, long	1·60 — 1·70
Pronotum, long 1·60 — 1·70; wide	1·14 — 1·30
Forewings, long 9·00 — 9·50; wide	2·70
Tibia iii, long	1·14

Locality.—N. Queensland: Townsville (G.F.H., 22.12.19, 6.1.20, 15.2.21).

Biology.—The association of this species with *Eutermes vernoni* Hill is referred to in an earlier paper (Hill, *P.L.S. N.S.W.*, xlvii. (2), 1922, p. 148, 2nd line).
Type in the author's collection.

A CORRECTION.

In my paper entitled "Termites (Isoptera) from South Sea and Torres Strait Islands," *Proc. Roy. Soc. Victoria*, xxxix. (1), 11th Nov., 1926, the reference to *Calotermes* (*Calotermes*) *repandus* Hill is given as "*Memoirs of the National Museum, Melbourne*, No. 7, in Press." The correct references are "*The Entomologist*," lix., Nov., 1926, p. 297, and "*Insects of Samoa*," part vii., 28th May, 1927, p. 6.

It should be noted also that owing to long delay in the Press, the description of the imago of *Calotermes* (*Glyptotermes*) *xantholabrum* Hill (*Mem. Nat. Mus.*, Melbourne, No. 7, June, 1927) is antedated by the subsequently written preliminary and full descriptions of the soldier caste in "The Entomologist," and "Insects of Samoa," of the above-mentioned dates, respectively.

ACKNOWLEDGMENTS.

Cordial thanks are extended to Mr. J. A. Kershaw, National Museum, Melbourne, to the collectors who have courteously made available the material dealt with in this paper, and to Messrs. G. McLennan, B.V.Sc., and D. Murnane, B.V.Sc., for the photomicrographic illustrations.

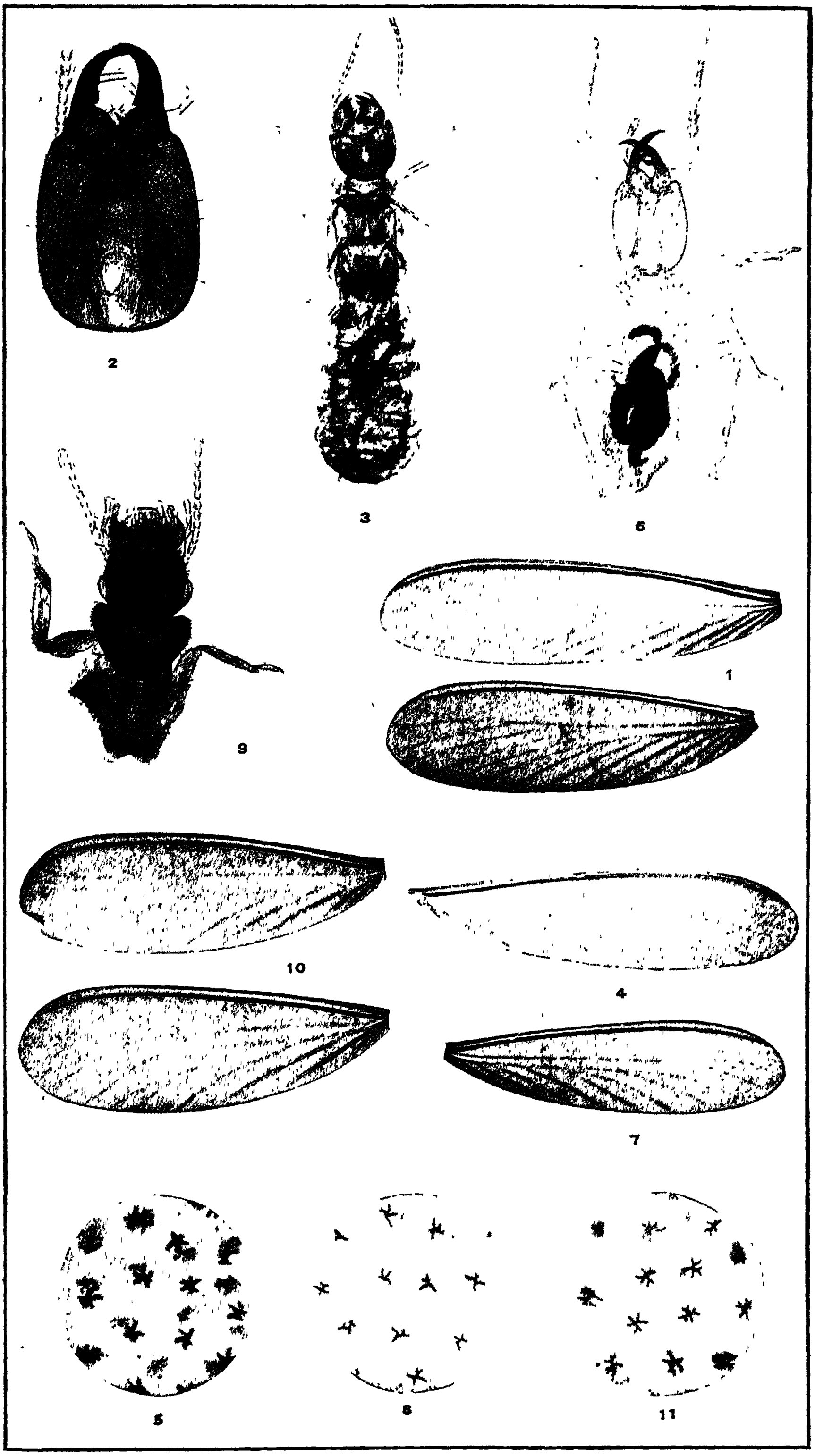
EXPLANATION OF PLATE XIV.

Figs. 1, 2.—*Hamitermes westraliensis*, n. sp.
" " 1. Imago: wings.
" " 2. Soldier: head.

Figs. 3, 6.—*Hamitermes tamminensis*, n. sp.
" " 3. Imago.
" " 4. Imago: wing.
" " 5. Imago: micrasters.
" " 6. Soldier.

Figs. 7, 8.—*Eutermes marcebensis* Hill.
" " 7. Imago: wing.
" " 8. Imago: micrasters.

Figs. 9, 11.—*Mirotermes insitivus*, n. sp.
" " 9. Imago: head and thorax.
" " 10. Imago: wings.
" " 11. Imago: micrasters.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[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. VIII.—*The Devonian and Older Palaeozoic Rocks of the Tabberabbera District, North Gippsland, Victoria.*

By

PROFESSOR ERNEST W. SKEATS, D.Sc., A.R.C.S., F.G.S.
(University of Melbourne).

(With Plate XV.)

[Read 11th October, 1928; issued separately 8th January, 1929.]

Introduction.

The geology of the Tabberabbera district has long been recognised as presenting interesting problems concerning the Middle Devonian sediments, because their lithological characters, as well as the subsequent earth movements which have affected them, present a contrast with the rocks of the better-known areas of Buchan and of Bindi in Eastern Victoria. As no geological work had been done in the region under discussion for over a quarter of a century, I welcomed the opportunities which arose in January, 1924, and January, 1925, of paying visits to the area. Through the kindness of Mr. W. Baragwanath, Director of the Geological Survey of Victoria, camping facilities were made available. Mr. Baragwanath joined me for the first four or five days of field work, Mr. J. Easton, Geological Surveyor, and his assistant (Mr. Norman Winter) were with me throughout the three weeks spent in the field, and Mr. Keble, of the Geological Survey, was with us for the last five days of the first trip, and Mr. Easton was with me during three weeks of the second visit. While I am responsible for the form and substance of this communication, I owe much to help rendered in the field by the gentlemen above mentioned.

Previous Literature.

The late Dr. A. W. Howitt, whose pioneering geological work in Gippsland was so remarkable, was the first to investigate the area about 50 years ago (1). His report is not only a valuable contribution to the geology of a wide area, but includes an exceedingly interesting account of a trip in bark canoes downstream from Tabberabbera through the gorge of the Mitchell River, accompanied by two aboriginals, Turnmile, meaning "one who swaggers," and Bungil Bottle, distinguished for his capacity for the absorption of strong waters.

The peculiar nature and compressed character of the mid-Devonian Tabberabbera shales was recognised and described and

their unconformable relations to the flat-lying beds of the Upper Devonian Iguana Creek series was recognised and figured.

Mr. E. J. Dunn (2) in 1890 published the account of a rapid survey of the area. His account refers to the presence of Silurian [Ordovician] rocks in Sandy's Creek, and of small areas of limestones in the Tabberabbera series. A sketch map accompanying Mr. Dunn's report shows the approximate distribution of the Silurian [Ordovician], Middle Devonian and Upper Devonian sediments.

Mr. O. A. L. Whitelaw (3) in 1899 published some sections illustrating the relations of rocks from the district, in a general account of Devonian rocks in Gippsland.

Mr. H. Herman (4), in June, 1899, published a short account of the Tabberabbera district with sketch geological map and section.

Mr. R. Etheridge (5), in 1899, gave identifications and descriptions of Silurian corals from Sandy's Creek.

Mr. T. S. Hall (6 and 7), described Upper Ordovician graptolites from Sandy's Creek.

Location of area and means of access.

The district described in this paper constitutes a roughly rectangular area of approximately 30 square miles. It lies within the Counties of Dargo and Wonnangatta, and includes parts of the parishes of Tyirra, Nungatta, Cobbannah and Morekana. The parish plans, on a scale of 2 inches to the mile, contain little topographical detail, and parts of them, in this sparsely settled region, are blank. The name of Tabberabbera does not occur on them, but is understood to refer to the scattered settlements close to the junction of the Mitchell and Wentworth Rivers. This lies about 40 miles WNW. of Bairnsdale, which is about 170 miles east of Melbourne. Tabberabbera, I understand, is an aboriginal name meaning Thunder, and in the months of January and February, during the occasional storms, the noise of thunderclaps reverberating among the hills of the district makes the naming appropriate.

The conditions of access to the district have much changed in the last forty years. Then it was difficult to reach the area, as there was no good graded road from Bairnsdale, but within the area access to various parts was readily made by good mining tracks, which were kept in repair, as alluvial and reef gold mining were then fairly active. Good grazing existed, as rabbits had not then invaded the district, so that, apart from the miners, there was a fair number of settlers running cattle, which assisted to keep the tracks open. Now there is a good graded and metalled road from Bairnsdale to Bullumwaal, and a good graded and formed road from Bullumwaal to Tabberabbera. But within the district mining has long ceased, mining tracks are overgrown, rabbits have come in, and therefore the country carries only a fraction of the cattle formerly

grazed. Settlement has, in consequence, declined, blackberries have over-run many of the gullies, and hop vine and other secondary scrub all contribute to make the district one in which it is not easy to do geological mapping. The district is rough and hilly, in places with steep, precipitous gorges, and in the months of January and February, apt to be uncomfortably hot. In the circumstances, much of the energy one would like to put into geological mapping is necessarily expended in the physical exertion of climbing, or of forcing one's way through scrub.

Nature of work done.

The total period of six weeks spent in the field allowed of some attention being paid to the stratigraphical and tectonic problems of the area, but, having regard to the fairly rugged topography, was insufficient for detailed mapping. The geological map which accompanies this paper, while it represents a considerable advance of knowledge over the earlier pioneer work, must be regarded as a sketch map. In particular, the boundaries shown for the Upper Devonian rocks are only roughly approximate, as this series was not the main object of study. The boundaries shown between Middle Devonian and Silurian rocks and between Silurian and Upper Ordovician rocks are based on more careful work, checked by palaeontological determinations kindly made for me by Mr. Chapman, Palaeontologist to the National Museum. Even these junctions, away from the sections exposed in the rivers, are only sketched in. It is clear, therefore, that until a detailed survey is made, some of the problems of stratigraphy and of tectonics cannot be completely solved, and such conclusions as are drawn in this paper are necessarily qualified by this consideration.

The sketch geological sections accompanying the map, and drawn nearly to the same vertical as horizontal scale, represent an attempt to illustrate the structure of the area.

Physical Features of the Area.

On approaching the area from Bullumwaal by road over the Upper Ordovician rocks, the following aneroid heights were noted:—Bullumwaal 735′, Burnett-Merrijig divide 1475′, Merrijig River crossing 1005′, Merrijig-Sandy's Creek divide 1475′, road crossing over upper part of Sandy's Creek 695′, Sandy's-Wentworth divide (at the Gooseneck) 1105′, Camp No. 1 460′, Wentworth R. level near Camp No. 1 450′. The rough timbered country of the Upper Ordovician series in the eastern part of the area rises, therefore, to a maximum of 1000 feet above the level of the Wentworth River.

The Silurian rocks occupying the northern central part of the area yield fairly open undulating country in the valleys, especially near the junctions of the Wentworth and Mitchell Rivers, and the

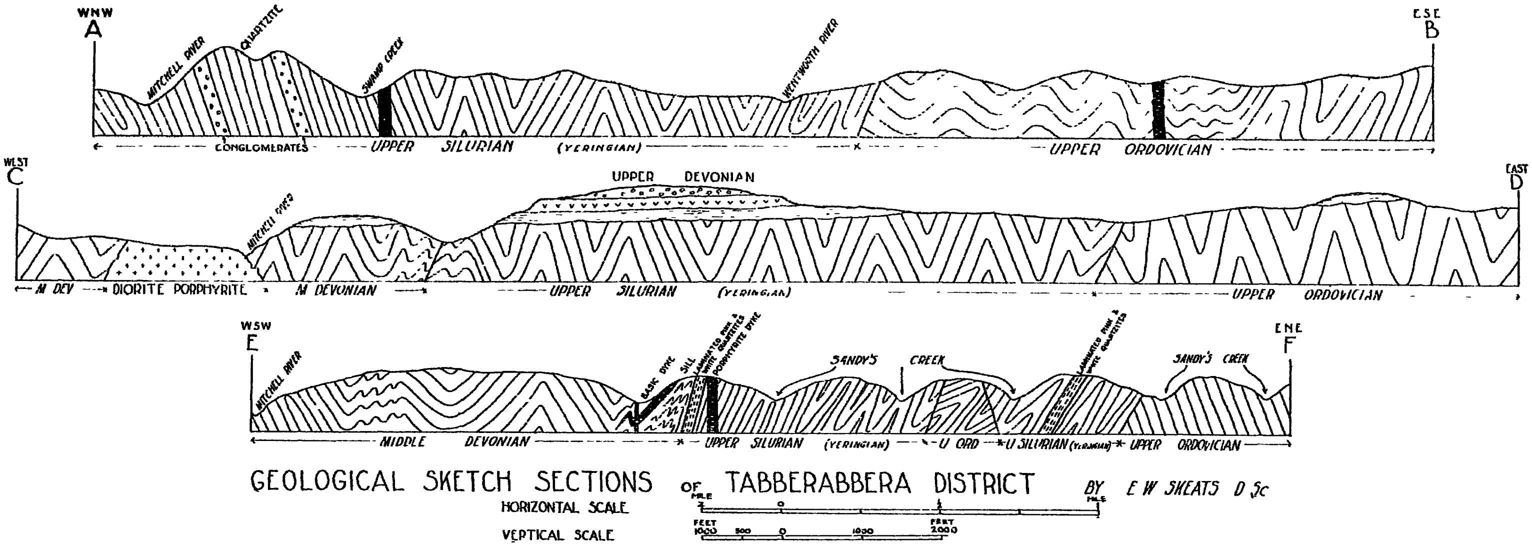
WNW
A
ESE
B
MITCHELL RIVER
QUARTZITE
SWAMP CREEK
WENTWORTH RIVER
CONGLOMERATES
UPPER SILURIAN (YERINGIAN)
UPPER ORDOVICIAN
WEST
C
EAST
D
UPPER DEVONIAN
MITCHELL RIVER
M DEV
DIORITE PORPHYRITE
M DEVONIAN
UPPER SILURIAN (YERINGIAN)
UPPER ORDOVICIAN
WSW
E
ENE
F
MITCHELL RIVER
BASIC DYKE
SILL
PORPHYRITE DYKE
SANDY'S CREEK
SANDY'S CREEK
MIDDLE DEVONIAN
UPPER SILURIAN (YERINGIAN)
U ORD
U SILURIAN (YERINGIAN)
UPPER ORDOVICIAN
GEOLOGICAL SKETCH SECTIONS OF TABBERABBERA DISTRICT BY E W SKEATS D Sc
HORIZONTAL SCALE
MILE
0
MILE
VERTICAL SCALE
FEET
1000
500
0
1000
FEET
2000

Fig. 1.

mouth of Swamp Creek. In following up Swamp Creek to the north a prominent sandstone hill to the NNE. is seen rising to about 1450', while to the west a very steep ridge of heavy conglomerates, rising to a height of about 1400', about 900' above Swamp Creek, forms a narrow divide with a steep slope to the West down to the Mitchell River. About 2½ miles up Swamp Creek its level by aneroid is 500', and beyond this the country is unfenced and becomes very rough.

The Middle Devonian rocks form a belt, trending about NW. across the area except in the south central part, where they are overlain by the Upper Devonian rocks. They are prominent near Ostler's and Horseshoe Bend, and to the north-west, and have weathered into undulating park-like country, grassed and with few trees.

The Upper Devonian rocks developed in the central part of the area form a rough dissected tableland rising in the central part to nearly 1500', and owing to a gentle south-west dip of about 5° descending by eroded terrace formations towards the Mitchell River. The Mitchell and Wentworth Rivers and Sandy's Creek all have well developed meanders and horseshoe bends, suggesting that the country had been formerly maturely dissected. Owing to late Tertiary uplifts all the streams were rejuvenated, and have trenched deeply into the underlying rocks. The whole course of Sandy's Creek below the Merrijig junction constitutes now a gorge-like valley, with steep cliffs of Upper Devonian on either side, overlying Ordovician, Silurian and Middle Devonian rocks, all of which slope steeply down to stream level, and in places form precipitous river cliffs. The Mitchell River, about 1½ miles below Ostler's, flows in a picturesque gorge, about 500 feet deep, cut through the Upper Devonian rocks for about a mile or so above the junction with Sandy's Creek. Just south of Camp No. 2, an abandoned course of the Wentworth River is shown by a broken line on the map, trending westerly, and then bending south to join Swamp Creek, just above its junction with the Wentworth River.

Geology.

Upper Ordovician.

Prior to my visits to the district definite Ordovician fossils had been obtained only from one locality (No. 9 on Map) on Sandy's Creek, about 25 chains above the junction with Merrijig Creek. These were obtained by Mr. Herman in 1897, and include *Glossograptus hermani, Dicranograptus ramosus* and *Didymograptus ovatus* (7). We revisited the locality and obtained similar specimens of these graptolites. Our examination of the road cuttings east of Camp No. 1, on the road going east towards Bullumwaal, yielded a number of graptolites, including *Diplograptus* sp. and *Glossograptus hermani,* from black cherty slates, interbedded with black cherts about half a mile south-east of Camp

No. 1 (No. 5 on Map). Traces of graptolites were found in similar black cherty slates for about a mile east of this locality. There can be little doubt that all these rocks in the eastern part of the area belong to the Upper Ordovician series, and as such they are shown on the map. The road section east of the Camp shows in addition to black slates and cherts, grey and brown micaceous sandstones and a considerable development of olive-coloured micaceous mudstones, some of which are finely laminated with thin beds of lighter and darker colour suggesting seasonal banding. Several lamprophyre dykes seen in road section $1\frac{1}{2}$ miles east of the camp are described later. One other small inlier of rocks older than the Silurian, and presumably Upper Ordovician in age. although no fossils were found in them, was found in Sandy's Creek. It occurs about $1\frac{1}{4}$ miles below the junction with the Merrijig Creek, as an elliptical area elongated in a north-westerly direction, and only about 200 yards broad. The rocks are black slates, similar to those containing Upper Ordovician graptolites, and quite unlike the Silurian rocks with which they are in contact. The boundaries of this inlier with the Silurian are probably determined by faults, while the main junction of the Ordovician and Silurian rocks may be determined either by faults or by an unconformity.

Silurian (Yeringian).

It is under this heading that the greatest changes are shown in the map accompanying this paper as compared with previous maps. Hitherto no Silurian rocks have been shown on any map of this area except in Sandy's Creek. As the result of my stratigraphic examination in the field and Mr. Chapman's valuable help in the determination of fossils from a number of localities, it is now known that a broad belt of country in the north-central part of the area and a limited belt in Sandy's Creek below the outcrop of Upper Ordovician rocks consist of Upper Silurian rocks, probably of Yeringian age. The large general geological map of Victoria, 1902, on the scale of 8 miles to the inch, shows as Silurian all the rocks of Sandy's Creek from the junction with the Mitchell River upstream for about 3 miles to just below the Merrijig Creek junction, where the Upper Ordovician rocks come in. Actually the occurrence of Silurian rocks in Sandy's Creek is limited in extent to a strip of country exposed on either side of Sandy's Creek, extending from about 300 yards below the Merrijig-Sandy's junction downstream for about a mile and a half. Even within this belt its continuity is interrupted by the small inlier of Upper Ordovician rocks previously referred to.

Some fossil corals from Sandy's Creek, probably collected by Mr. Herman in 1897, were described by Mr. Etheridge (5) in 1899 as Upper Silurian. The locality was probably from an outcrop of impure limestone about 200 yards upstream from the Upper Ordovician inlier, since we found at that spot similar genera to those described by Mr. Etheridge. The forms he described are

Diphyphyllum porteri var. *mitchellensis,* var. nov., U. Silurian, *Rhizophyllum interpunctatum* De Koninck, U. Silurian, *Monticulipora (Heterotrypa) australis*, sp. nov., U. Silurian.

The 1902 map, eight miles to the inch, shows a great area coloured as Middle Devonian limestone, which starts about two miles south of Tabberabbera, and continues northwards for about 18 miles. It is shown extending for two or three miles east of the Wentworth River, and has a maximum breadth of about eight miles, gradually becoming narrower in its northerly extension. The later general geological map of Victoria, 1909, on a scale of 16 miles to the inch, gives this area the colour appropriate to the Upper Devonian sandstones and shales. This is lithologically more correct, but from the point of view of age appears to be further from a correct determination than that shown in the earlier map. My own observations in the field have only extended to a point on Swamp Creek, about three miles north of Tabberabbera, but the rocks up to that point show similar lithological characters to those nearer Tabberabbera, such as localities 1, 2, 3 and 6, on the map, from which abundant fossils, determined by Mr. Chapman as Upper Silurian (Yeringian), have been obtained. It seems certain, therefore, that the southern part of this area up to three miles north of Tabberabbera, consists of Silurian and not of Middle or Upper Devonian rocks, and it is probable that the whole of this area, extending to about 18 miles north of Tabberabbera, consists of rocks of Silurian age.

The localities 1, 2, 3, and 6 from which we obtained abundant fossils occur north and south of the junction of the Mitchell and Wentworth Rivers, which Howitt named as Tabberabbera.

Loc. 1. Allot. 13, S. Websdale, Tyirra.
Fossils—*Bythotrephis* cf. *gracilis* J. Hall.
Spirifer aff. *crispus* (Hisinger).
Yeringian.

Loc. 2. Allot. 14, Tyirra
Fossils—*Spirifer* aff. *crispus* (Hisinger).
Ctenodonta cf. *portlocki* Chapman.
Yeringian.

Loc. 3. Allot. 9A, E. Desailly, Tyirra.
Fossils—*Spirifer* aff. *crispus* (Hisinger).
Pentamerus aff. *lens* (Sowerby).
? *Glossites* or ? *Palaeoneilo.*
Actinopteria sp.
Yeringian.

Loc 6. Allot. 6, Nungatta. E. bank of Mitchell River, about half mile south of Birch's.
Fossils—Plant remains, ind.
? *Tryplasma.*
Chollotrypa sp.
cf. *Favosites gothlandica* Lam.
Roemingeria sp.
cf. *Leptaena* sp.
Atrypa aspera (Schloth.). Gerontic forms.
Conchidium sp.
Spirifer sp., probably new.
Yeringian.

This evidence shows that the type locality for the Tabberabbera shales at the junction of the Mitchell and Wentworth Rivers actually consists of Upper Silurian rocks. Dr. Howitt (1, page 206) states: "I found a small limestone patch at Tabberabbera, situated at the junction of the Mitchell and Wentworth Rivers. No fossils have been procured from the limestone, but associated with them are black shales, yielding plentifully the *Spirifera laevicostata* [later redescribed as *Spirifer yassensis*] and a *Grammysia*. They are regarded by Professor McCoy as being of the same age as the Buchan limestones, and therefore Middle Devonian."

To reconcile these statements with the evidence I have obtained, it is necessary to interpret very loosely Howitt's word "associated" in connection with the black shales yielding the above forms. It is almost certain that Howitt did not obtain them from the junction of the Mitchell and Wentworth Rivers, and I was unable to locate such black shales at this junction. It is probable that he obtained them from a locality on the Mitchell River, about three miles below Tabberabbera.

He figures (1, p. 207) a sketch section No. 16 Tabberabbera, showing the fossiliferous black shales on the east side of the Mitchell River, and just below the junction with the Upper Devonian (Iguana Creek) beds. His statement is that the section is "below Tabberabbera." Further on (1, p. 215), when describing his canoe journey down the Mitchell, he states that they started about two miles below Tabberabbera, and after continuing some time he landed and examined a limestone which he states was "very much upon the line of section given in sketch No. 16." It is not possible to locate this place exactly from Howitt's description, but I take it to be about one mile down stream from Ostler's. If that is so, the difficulty disappears, since I have obtained Middle Devonian fossils at Horseshoe Bend and east of Ostler's and rocks of a similar character continue down stream for some distance.

Loc. 4, at the road cutting on the north side of the Wentworth River, about half a mile west of Camp No. 1, provides another fossiliferous locality in the Silurian series. The rocks are finely laminated black and brown cherts crowded with Radiolaria. Mr. Chapman has reported on microscopic sections of these rocks as follows:—

"The rock is crowded with radiolarian remains, but only very few are determinable. In some cases the ferruginous staining and replacement of the siliceous test is an aid to deciphering the form and structure."

Genera or species noted—

Distriactis sp.
Acanthosphaera cf. *etheridgei* Hinde.
Stylosphaera sp.
Spongoloncha cf. *lens* Hinde.

The assemblage closely resembles that from the Tamworth district, described by Hinde in *Quart. Journ. Geol. Soc.*, vol. lv., 1899, pp. 38-64."

Lithological types in the Silurian rocks of this district are numerous and varied. The sections exposed in the road cuttings between localities 4 and 2 on the map, are in a zone of great crushing and contortion. Olive mudstones and dark calcareous shales, some very fossiliferous, are common. In places where the calcium carbonate has been leached out the rocks are rusty brown in colour, and the fossils are only preserved as casts. Thin lenticular blue limestones were also noted. Sandstones and grits are fairly prominent. Calcareous mudstones and thin blue limestones occur also south and north of Loc. 6, South of Birch's. An impure blue limestone in Sandy's Creek about 200 yards above the Upper Ordovician inlier yields an abundant supply of Silurian corals.

Two parallel massive and thick conglomerates with intercalated grits are shown on the map, extending from east of E. Websdale's down to the Mitchell River, and a smaller conglomerate and grit higher in the Silurian series are shown east of Swamp Creek.

The pebbles in the most westerly conglomerate near E. Websdale's are up to a foot in length, and are much dimpled and sheared. Fine-grained laminated pink and white sandstones or quartzites were noted about two miles up Swamp Creek adjoining the big dyke shown on the map, and were seen again on the Mitchell River about one mile west of Sinnott's, and very similar types occur in two places in the Sandy's Creek section, one adjoining the western boundary of the Silurian and the other near the eastern boundary of the same series.

Numerous dykes intersect the Silurian rocks. Many appear to have a similar strike to that of the adjoining sediments, others cut across the strike of the sediments at various angles. They include hornblende porphyrites, some fresh and others calcareous with decomposition, quartz felspar porphyries, black dykes showing quartz, and a tinguaite. Brief petrological descriptions of some of these are included later in the paper.

Middle Devonian.

The rocks to which a Middle Devonian age can be assigned are restricted, as shown on the map, to a belt of country occupying the western part of the area.

The junctions with the Silurian rocks to the east have been definitely located only in two places. One is near Loc. 7, on the Mitchell River, east of the saddle of Horseshoe Bend. The other is in Sandy's Creek, just above Whitbourne's Hut, and just east of a prominent sill or interbedded flow near a crush zone, and just west of prominent laminated pink and white quartzites.

Below this point on Sandy's Creek, down to the junction with the Mitchell River, the whole sequence for about 1½ miles across the strike is in the Middle Devonian sediments, and characteristic

Middle Devonian fossils have been collected from several bands of blue limestone or dark calcareous shales exposed in the river cliffs.

One limestone band a few hundred yards below Whitbourne's flat yielded in microscopic sections, according to Mr. Chapman's determination—

Spirifer yassensis.
? *Coenites* or *Campophyllum?*
Carapaces of Ostracods, chiefly *Primitia.*
Syringopora?
Foraminifera including *Pulvinulina?*
Nubecularia?
Crinoid ossicles.

From Loc. 7, just east of the saddle of Horseshoe Bend, abundant fossils were obtained, chiefly as casts, which Mr. Chapman has determined as under:

From a shale band—

Spirifer yassensis de Kon.
Grammysia sp.

and from a limestone band—

Abundant specimens of *Spirifer yassensis* de Kon.

Similar fossils were also obtained at Loc. 8, south of Horseshoe Bend and east of Ostler's. The lithological types in the Middle Devonian include blue limestones, black, brown and yellow shales or slates, some silicified or flinty shales and siliceous sandstones. The rocks at Horseshoe Bend are intensely crumpled, faulted and in places vertical.

Numerous dykes penetrate these rocks, and are especially noticed in the ridge-like saddle of Horseshoe Bend and south from that locality; some striking E. and W., others conforming more or less to the strike of the sediments either W. or E. of north. They include hornblende and other types of porphyrites; at Loc. 8 a tinguaite strikes E. and W.; at Whitbourne's flat on Sandy's Creek an interbedded igneous rock occurring as a sill or lava flow is a fine-grained porphyrite; and S. of Whitbourne's flat a big black basaltic dyke cuts across the sediments. South of Ostler's, where the Mitchell bends to the west, the slopes below the Upper Devonian series consist of a large area of diorite porphyrite, probably intrusive into the Middle Devonian sediments (see Section C-D).

Upper Devonian.

The rocks of this series, provisionally described as of Upper Devonian age, occur within the central and south-western parts of the area shown on the map. They form a series about 900 ft. in thickness. They rest in turn on the heavily eroded edges of folded rocks of the Upper Ordovician, Upper Silurian and Middle Devonian series, and as they themselves are almost horizontal, their dip being not more than 5° to the SW., their relations with the older rocks, even with the Middle Devonian, constitute a very important and striking angular unconformity.

They have not in this district as yet yielded any recognisable fossils, and the validity of the reference of them to the Upper Devonian depends on questions of geological continuity and of lithological correlations with other areas. The following rough section, supplied to me by Mr. J. Easton, and trending in an approximately easterly direction from the Mitchell River above Horseshoe Bend, and just north of Loc. 7, will serve to illustrate the sequence of the rocks of this series. At the base, about 150′ above the level of the Mitchell River, and resting directly and unconformably on the eroded surface of the folded Middle Devonian mudstones and shales, are about 100 feet of purple grits and mudstones, then a few feet of purple breccia followed by about 60 feet of purple mudstone. About four feet of nodular or spherulitic rhyolite comes next, followed by 90 feet of red and grey mudstone, then 20 feet of breccia and conglomerate, 50 feet of mudstones, 3 feet of rhyolite, 70 feet of conglomerate and breccia, and continuing to the top of the series developed in this district about 500 feet of siliceous and pebbly grey sandstone beds.

The precise sequence of these rocks varies somewhat in different parts of the area shown on the map. In some places the interbedded rhyolites are much thicker, and just east of the diorite porphyrite about a quarter of a mile south of Loc. 8 the sequence appears to start with spherulitic rhyolites.

The reference of these to the Upper Devonian is not quite certain, since, as shown on the map, they have a dip of 30°, and it is just possible that they may unconformably underlie the base of the Upper Devonian, and may be a small area of Lower Devonian igneous rocks. If this were so the diorite porphyrite on which they appear to rest would be older than is shown in the sketch geological section.

On the whole, however, it is thought to be more probable that these spherulitic rhyolites are of Upper Devonian age, and that their relatively high and abnormal dip is due to restricted local movement. This view is strengthened since A. W. Howitt (18) in describing the sequence of Upper Devonian rocks in the Snowy Bluff section, refers to interbedded compact felsites (felstones), having in places a spherulitic structure, the spherules being from one to two inches in diameter.

This description corresponds closely with the nature of the spherulites just east of the diorite porphyrite, and is in accordance with their recurrence higher in the series as noted by Mr. Easton in the section described above.

In most parts of the area, however, purple mudstones form the base of the series. No interbedded basalts (melaphyres of Howitt) have been found " in situ " in these rocks, but they probably occur, since abundant pebbles of this type of rock have been found at the Mitchell River at and near Loc. 7. I have not seen any dykes penetrating these rocks, but Mr. Easton informs me of the interesting fact that he has obtained a lamprophyre and several felspar porphyrite dykes intruded into the Upper Devonian sediments.

The lithological characters of these rocks and their prevalent purple and red colours suggest that the series is a lacustrine one, rapidly accumulated in an arid climate subjected to occasional rain storms.

Tectonic Movements and Structures.

The district has clearly suffered from successive movements of compression in post-Upper Ordovician, post-Upper Silurian, and post-Middle Devonian times, and in the Silurian and Upper Ordovician rocks it is almost impossible to distinguish the effects of the earlier from those of the later movements.

The present relations expressed in dips, strikes, trends of fold axes and trend of boundaries between different formations have developed as the result of the combined effects of all the earlier and later structural movements.

The structural features in the Ordovician rocks are fairly clearly shown in the road section, starting from about half mile from Camp No. 1, and continuing for about 2½ miles in a general easterly direction. The distribution of dips and strikes shown on the map indicates that away from the junction with the Silurian the average strike is about N.20°E. and the average dip about 65°-70°. Near the Silurian junction the strikes are much more disturbed, and trend west of north at varying angles from NNW. to W. It would seem that near the Silurian junction along this road section is a zone of special disturbance, and since it will be seen that the Silurian rocks near this junction also tend to have abnormal strikes it may be that either this junction was determined by post-Silurian fault movements or, if the junction be an unconformity, that the post-Silurian movements were only able to impress themselves on the indurated and compressed Ordovician rocks in the neighbourhood of the junction with the Silurian.

The section in Sandy's Creek above the Merrijig junction shows an abnormal strike of N.70°W. This locality is about half mile from the junction with the Silurian. About a mile below the junction the small, probably faulted, inlier of Ordovician rocks has a strike of N.30°W., and an unusually low dip of 20°. This latter may well be an effect of overfolding.

The general strike of the Ordovician east of north, away from the Silurian contact, is in harmony with the evidence given by Teale (10) from Nowa Nowa, and farther east in Croajingolong. In this part of Victoria the trend of the Palaeozoic rocks and of their junctions, as seen on a general geological map, is east of north, and continues in this direction into New South Wales. But northwards from a line through Mt. Wellington, Waterford to Mt. Baldhead, the trend of the junctions of Upper Palaeozoic and Lower Palaeozoic rocks is about N.40°W., and strikes of this nature are common in the Ordovician rocks north of the line mentioned. Both sets of trend lines must be of post-Palaeozoic development, or at any rate continued till late Palaeozoic times,

since the trend of the junction of the Upper Devonian and Upper Ordovician rocks in the northern area conforms to the direction of N.40°W.

The structural features in the Silurian (Yeringian) rocks are comparatively simple in the sections seen in Sandy's Creek. The strikes are all west of north, varying from 20° to about 40° west of north. The lines of junction with Upper Ordovician and with Middle Devonian rocks appear to trend about N.40°W.

Much greater diversity of strikes and complexity of folding occur in the central and northern part of the area in sections seen on the Mitchell and Wentworth Rivers and in Swamp Creek on the bare exposed saddles within this part of the region.

West of a north and south line through Camp No. 2, the strikes are all west of north at angles varying from N.20°W., which is a common strike in the western outcrops, to N.65°W., in several places near Loc. 6. In the road sections east of Camp No. 2, and in one or two localities further north, the strikes are all east of north from 20°-50°, except in one case south-east of Camp No. 1, adjoining the junction with the Upper Ordovician. A dyke and grits strike north and south about one mile north of Camp No. 2. On either side of this there is a tendency to a convergence of strike of the beds to the south, suggesting a syncline pitching north. A prominent grit bed on the Wentworth River just north of Birch's shows an axis of a syncline. However, the prominent conglomerate beds shown on the western part of the map continue with a strike of N.20°W. in a southerly direction at least to the Mitchell River. There may be a strike fault east of these conglomerates, and the big dyke seen along Swamp Creek may have been intruded along such a fault. The average dip of the Silurian rocks is very high. The only one as low as 45° occurs near the Middle Devonian junction north-east of Loc. 7. In many cases the beds are vertical, and perhaps the average dip on either side of the fold axes is 70° to 75°. A puckered anticline and syncline with steep northerly pitch occur at Loc 7 at the junction with the Middle Devonian rocks. While the high dips and the fold axes are the expression of compressional earth movements, the numerous dykes intersecting the Silurian rocks indicate that tensional cracks either accompanied or succeeded the compressive movements within the same geological period or at later times.

The majority of the dykes in the Silurian, especially the porphyrite dykes, appear to strike nearly or quite parallel to the adjoining sediments, but near Horseshoe Bend two dykes, one of them a tinguaite, cut right across the strike of the sediments in an east-west direction.

The structural features in the Middle Devonian rocks have been noted near Horseshoe Bend, near Localities 7 and 8, and in continuous sections along Sandy's Creek for about 1½ miles across the strike upstream from its junction with the Mitchell River.

In the first locality considerable changes in strike direction are noticeable from N.10°E. to N.20°W., while on the saddle in the neck of Horseshoe Bend a porphyrite dyke strikes east and west and farther south at Loc. 8 a tinguaite dyke strikes in the same direction. The rocks in this locality are very steeply folded and crinkled, with dips of 75° to 80°. At Ostler's and south of the Mitchell River south of Ostler's, there is a large area of intrusive rock, dark green in colour, consisting of diorite porphyrite. Howitt also noted the occurrence of a similar rock further down the Mitchell River in a locality which I have not been able to visit. The boundaries and field relations of this rock were not determined, but it is probable that it represents a hypabyssal intrusion of post-Middle Devonian age.

On Sandy's Creek the strikes of the rocks and the fold axes are uniformly west of north, usually about N.20°W. Several anticlinal and synclinal folds are seen in section in the river cliffs, and usually the dips on either side of the axes are at 45°-50°. Dips up to 80° are, however, recorded, and at one of the anticlinal folds severe local puckering and faulting complicate the relations. At the junction with the Silurian rocks just above Whitbourne's Hut, while the dip is westerly, there is a zone of puckering and overfolding with an intercalated fine-grained sill or lava seen in the cliff section. It is clear from these facts that in this region there is evidence of local severe compressive earth movements later than the Middle Devonian. Teale (10) has noted that at Hickey's Creek on the Macallister River, there occurs a local severe tectonic zone of faulting and synclinal folding, which is of post-Upper Devonian age since rocks of this age are involved.

In the Grampians in Western Victoria the author (11) has given evidence of post-Lower Carboniferous plutonic intrusions. The evidence cited from these localities shows that the long maintained view that notable compressive earth movements with accompanying plutonic intrusions ceased in the Lower Devonian period cannot now be entirely accepted.

In Central Victoria the similarity of composition of dacites and granodiorites suggests that although the granodiorites are instrusive into the dacites, they probably belong to the same period of igneous activity, which has been regarded as probably Lower Devonian, since in various places the dacite series is overlain unconformably by Upper Devonian sediments. At Bindi, the Middle Devonian limestones and shales rest possibly unconformably on the Snowy River porphyrites of Lower Devonian age, and are only gently folded. At Buchan, pyroclastic igneous rocks associated with the Snowy River porphyrites, are intercalated with the lower part of the limestones and shales. In the Buchan district the structural relations of the limestone series are seen from numerous recent road sections to have been affected in general by only gentle post-Middle Devonian compressive movements since the average dips seldom exceed 20° except in one or two places, where quite local puckers have developed small anticlinal folds with high

dips. At Buchan and Bindi, therefore, the gentle folding stands in marked contrast to the more severe compression which has affected the Silurian rocks generally in Victoria and the Middle Devonian rocks of Tabberabbera.

The rocks described as Upper Devonian in this district have not suffered from any compressive earth movements. They appear in the sections exposed in the field to be almost horizontal, but a dip of about 5° to the south-west can be inferred from the fact that rhyolites and other associated rocks outcropping at river level along the Mitchell at about 400′ elevation are over 1000′ above sea-level about two miles E.N.E. from that locality.

Significance of the Unconformity between the Middle and Upper Devonian Rocks.

The most remarkable structural features of the district are firstly, the severe compression and folding which have affected the Middle Devonian rocks, whose age is definitely determined by their fossil content, and secondly, the profound character of the unconformity which separates these folded rocks from the flat-lying sediments and lavas which rest on their denuded edges and also unconformably overlie the Silurian and Upper Ordovician rocks. These overlying rocks are here described as Upper Devonian, but the question of their age invites some discussion. As stated above, no fossils have as yet been found in these rocks, but they appear to be geologically continuous, as stated by R. A. F. Murray (17), with the series developed further south at Iguana Creek, and south-west at the Avon River. There is continuity and similarity of sedimentation in all three areas, but McCoy (11) described the Avon River beds as Lower Carboniferous, on account of the presence in them of *Lepidodendron australe,* and the Iguana Creek Beds (12) as Upper Devonian on account of the presence in them of *Cordaites australis* and *Archaeopteris Howitti.*

A broad belt of similar sediments stretches N.40°W. from the Avon River through the Mt. Wellington district, described by Teale (10), to Mansfield. Near Mansfield, on the Broken River, Cresswell and, later, George Sweet (14) discovered plants and fossil fish partially described by McCoy (13) as showing forms of mingled affinities ranging through Lower Devonian, Upper Devonian to the base of the Carboniferous. McCoy placed the Mansfield Beds as at the top of the Upper Devonian. It should be noted that McCoy identified the plant remains as *Lepidodendron Mansfieldense,* a species quite distinct from the form met with in the Avon River section. Smith Woodward (15), however, later described the Mansfield fossil fish as typically Lower Carboniferous, and the Geological Survey of Victoria, in their latest general geological map of the State (1909), on the scale of 16 miles to the inch, have distinguished the beds round Mansfield from the rest of the belt of similar rocks, colouring them as Car-

boniferous, and the rest, including the Avon River beds, as Devonian. In numerous localities in New South Wales, as at Mt. Lambie and Tamworth, New South Wales geologists have shown that, in that State, *Lepidodendron australe* is interbedded with marine beds containing Devonian marine fossils, at Tamworth with radiolarian cherts described as of Middle Devonian age, and at Mt. Lambie and elsewhere interbedded with marine beds containing *Spirifer disjuncta,* a typical Upper Devonian brachiopod. Professor Benson (16) has given a full discussion on the Devonian palaeontology of Australia and discussed the stratigraphical implications.

Our Victorian problem is to reconcile the geographical continuity over a wide area of fairly flat-lying beds of similar lithological types, and apparently one series formed under similar conditions, with the palaeontological determinations which would place the Avon River Beds on plant determinations as Lower Carboniferous, the Mansfield beds as Lower Carboniferous on identification of fossil fish, and the Iguana Creek beds as Upper Devonian on the identification of fossil plants.

The reconciliation of these apparent anomalies will probably not be achieved until continuous and detailed geological surveys are made throughout the broad belt of rough mountainous country between Iguana Creek and the Avon River, and between the Avon River and Mansfield. Until this work has been accomplished the point of view expressed on the Geological Map of Victoria in 1909—the separation of the Mansfield area from the remainder—appears to have some justification.

The important evidence from various localities in New South Wales that *Lepidodendron australe* is there an Upper Devonian form may justify us in Victoria in regarding the Avon River beds as well as the Iguana Creek beds as of Upper Devonian age.

In this connection it is perhaps pertinent that the broad belt shown on the Geological Survey Map of Victoria, 1909, as Devonian, is an area throughout which there are intercalated with the conglomerates, sandstone and shales, important flows of rhyolite and thinner sheets of basic lavas (melaphyres of Howitt) and similar intercalated igneous rocks are recorded from several of the New South Wales areas in which Upper Devonian rocks are recorded. But in the Mansfield area these intercalated igneous rocks have not been found. Despite then the similarity of the sediments in the Mansfield district to the sediments farther to the south-east, the absence of contemporaneous lavas in the Mansfield area, may be regarded as negative evidence supporting the positive evidence of the fossil fish described by Smith Woodward as fixing a Lower Carboniferous age for the Mansfield beds.

The foregoing discussion then may justify us in accepting, at any rate provisionally, the flat-lying sediments with intercalated lavas of the Tabberabbera district as of Upper Devonian age.

If this view is correct the significance of the gigantic unconformity between these beds and the highly crumpled Middle

Devonian rocks beneath is remarkable and difficult to explain, for we have to picture that in this part of Victoria in the geologically short interval between Middle and Upper Devonian the sea receded, the Middle Devonian rocks were crumpled and elevated, and denuded to a low-lying area, before the lacustrine conditions of the Upper Devonian were established.

Petrographic Characters of the Igneous Rocks of the District.

In this paper, mainly concerned with structural and stratigraphical relations, only brief descriptions of the igneous rocks will be given. The reference numbers are those of the main collection of rock sections in the Geological Department of the University of Melbourne.

Dykes of varying size and petrologic character occur in the Upper Ordovician, Silurian (Yeringian), Middle Devonian and Upper Devonian (Easton's communication) rocks.

A big hypabyssal or small plutonic intrusion of diorite porphyrite occurs in the Middle Devonian rocks as well as an intercalated sill or lava flow.

Prominent nodular or spherulitic rhyolites, as well as banded flow rhyolites, occur in the Upper Devonian, and the evidence of boulders in the river-beds suggests that basic flows (melaphyres) may also be represented in the Upper Devonian, although they have not yet been found "in situ."

In the Upper Ordovician sediments, apart from spherulitic keratophyres, and a hornblende porphyrite, high up Sandy's Creek, near the Bullumwaal road, the only dykes found up to the present are somewhat decomposed mica lamprophyres. A boulder of a somewhat similar rock found about two miles up Swamp Creek suggests that mica lamprophyres may also penetrate the Silurian rocks, while a boulder of a fresh green tinguaite, No. 1726, found about three miles up Sandy's Creek, indicates that a dyke of this type probably intruded the Ordovician sediments. Within the Silurian (Yeringian) rocks, dykes of hornblende porphyrite, felspar porphyrite, quartz felspar porphyrite, oligoclase trachyte and of tinguaite, No. 1737, have been found, and a boulder of fresh tinguaite, No. 1718, was found in the Mitchell River, about half a mile below E. Websdale's house. This represents material from a dyke which may intersect either Silurian or Upper Ordovician rocks, since the Mitchell River above this point drains areas of both these series. Dykes penetrating the Middle Devonian sediments include numerous porphyrites, a basalt and a tinguaite, No. 1727. It will be noted that four felspathoid-bearing rocks are now known from this district. The author (8) has given petrographic descriptions of them recently, so that it is not necessary to refer to them further, except to point out that within

recent years it has become known, by the author's contributions to recent volumes, as one of the Secretaries to the Alkaline Rocks Research Committee of the Australasian Association for the Advancement of Science, that Eastern Victoria must be regarded as an alkali-rich province. Phonolites and tinguaites have been recorded by him from the Tolmie Ranges, near Mansfield, from Pretty Boy pinch, west of Tabberabbera, from near Mt. St. Bernard, north-north-west of Tabberabbera, and from near Omeo, north of Tabberabbera. Many of these are so fresh and unaltered that they may quite likely be of Middle to Late Kainozoic age, like the alkali rocks of Mt. Macedon and the Western District of Victoria. If this is so, they may have been intruded along tension cracks associated with the successive plateau elevating movements, differential in character, which have uplifted Eastern Australia. It cannot, however, be said that their association with fault movements has yet been proved or definitely established.

Descriptions of Rock Sections of Igneous Rocks.

1608. Dyke 10′ thick, road cutting in Upper Ordovician, 1½ miles east of Camp No. 1.

A dense dark fine-grained rock in hand specimen, weathering to a rusty brown colour. Pale to pink "Schlieren" occur through it and occasional large plates of biotite are present. Under the microscope brown biotite is abundant, green and brown sub-porphyritic hornblendes, and small prismatic green to brown crystals of the same mineral are abundant. Large clear zoned crystals of plagioclase are invaded by the ferromagnesian minerals and the ground mass is partly cloudy through the alteration of the smaller felspars, while "Schlieren" are represented by clear colourless areas, partly consisting of felspar, and isotropic areas which occur suggest that a felspathoid such as sodalite may be present. The rock may be described as a mica hornblende lamprophyre.

1723. Dyke through Upper Ordovician in the upper part of Sandy's Creek, near the Bullumwaal road.

In hand specimen the rock is rather decomposed, cream-coloured, and apparently largely felspathic. Under the microscope it is seen to be practically wanting in ferromagnesian minerals, and to be composed almost entirely of felspar. A few areas of almost colourless chlorite indicate the former presence of a small amount of a ferromagnesian mineral. A number of small quadrate to lath-shaped clear felspars with fine twin lamellae and almost straight extinction consist of oligoclase, while the bulk of the rock consists of spherulitic aggregates of felspar laths. The rock may be described as a spherulitic keratophyre.

1738. Dyke penetrating Upper Ordovician high up Sandy's Creek near Bullumwaal road.

In hand specimen the rock appears to be fairly fresh, dark grey in colour, fine grained with small porphyritic crystals. Under

the microscope the rock consists mainly of two minerals. Plagioclase is abundant as fair sized porphyritic fresh crystals of quadrate habit and moderate extinction angle indicating andesine. Somewhat later than the felspar is abundant pale hornblende, some of which is altered to chlorite. A little magnetite in crystals and irregular grains is also present. The rock is a rather basic hornblende porphyrite.

1730. Dyke cutting Upper Ordovician high up Sandy's Creek, about one mile below Bullumwaal road.

In hand specimen the rock is cream coloured, with porphyritic quartz. Under the microscope large corroded crystals of quartz showing crystal boundaries are common, and large abundant phenocrysts of plagioclase ranging from oligoclase to andesine are set in a fine groundmass of spherulitic aggregates of felspar. Small microscopic quartz veins penetrate the rock. The rock may be described as a porphyritic and microspherulitic quartz keratophyre.

1724. Weathered dyke cutting Silurian, 250 yards NE. of Loc. 2.

The hand specimen is a dense fine-grained brownish grey rock, with porphyritic felspars. In section its altered character is apparent. All the larger felspar phenocrysts are kaolinized. Smaller quadrate phenocrysts are oligoclase, as is most of the felspar in the felted groundmass. The ferromagnesian mineral has altered to chlorite and a small amount of secondary calcite is present. The rock may be described as an oligoclase trachyte.

1747. From big dyke cutting Silurian shown on map along Swamp Creek, from quarter mile below top fence.

In hand specimen the rock has a rather coarser texture than most of the dykes seen, and shows small phenocrysts of felspar and hornblende. Under the microscope both plagioclase and hornblende are abundant, each is in turn porphyritic, and each may be included in the other, suggesting almost simultaneous crystallization. The groundmass consists mainly of small plagioclase felspars. The felspar is mainly oligoclase, the hornblende is pale, and some amount of minute magnetite is present, and secondary calcite occurs in small amount. The rock is a hornblende porphyrite.

1743. From same dyke as 1747, but 10 chains lower down Swamp Creek.

In hand specimen its paler colour and more altered appearance than 1747 is noted. Under the microscope it is distinguished from 1747 by the absence of hornblende, and the abundance of secondary calcite and the presence of a fair amount of quartz in the groundmass. The rock is an altered felspar quartz porphyrite.

1606. Dyke penetrating Silurian, road east of Loc. 2, at northwest corner of Allot. 9, R. J. Oates.

In hand specimen the rock is dense, cream-coloured, with porphyritic quartz crystals. Under the microscope large phenocrysts

of oligoclase, andesine and of corroded quartz crystals are set in a micrographic groundmass of quartz and acid plagioclase. The rock is a micrographic quartz felspar porphyrite.

1719. Dyke cutting Silurian and striking north and south from hill east of Swamp Creek. Allot. 2, K. Sinnott.

In hand specimen the rock is dense and cream-coloured, with porphyritic felspars and quartz. Under the microscope phenocrysts of untwinned felspar and of corroded quartz are set in a microcrystalline groundmass of quartz and felspar, consisting of both plagioclase and orthoclase. Some elongated biotite more or less altered to chlorite is also present. The rock is a quartz felspar porphyry.

1744. Big dyke 110′ thick, penetrating Silurian near western boundary, 250 yards above Whitbourne's Hut, Sandy's Creek.

In hand specimen the rock is dense and dark greenish in colour, with small felspar phenocrysts. Under the microscope the rock is seen to be considerably altered. The plagioclase phenocrysts are decomposed, and the hornblende replaced by chlorite and abundant calcite. The groundmass contains small crystals of magnetite, but consists mainly of a microcrystalline aggregate of felspar, with some quartz. The rock is an altered hornblende porphyrite.

1739. Black dyke cutting Silurian conglomerate on Mitchell River, west of Sinnott's.

In hand specimen the rock is black and densely crystalline. Under the microscope it is seen to be fresh with ophitic texture since lath-shaped labradorite penetrates pale brown augite, a little of which is altered to chlorite. Irregular crystals of magnetite are fairly abundant. The rock is a dolerite.

1733. Big dark dyke cutting Silurian quartzites, and striking N.10°W. near bend in Mitchell River, west of Sinnott's.

In hand specimen the rock is a black fine-grained but crystalline rock with felspar phenocrysts. Under the microscope it is seen that the rock has suffered dynamic alteration. Porphyritic plagioclase felspars are set in a finer ophitic intergrowth of felspar laths and ferromagnesian minerals, but the latter are now fibrous hornblende and the plagioclase has been mostly recrystallized to radiating or needle-shaped secondary minerals. Fine-grained irregular crystals of magnetite occur in the groundmass. The rock is a fine-grained dynamically altered dolerite.

1746. Dark dyke striking east and west, eight chains NW. of saddle of Horseshoe Bend.

In hand specimen the rock is a dark grey fine-grained crystalline rock. Under the microscope the rock is seen to consist of large lath-shaped labradorite, with prismatic to irregular pale purplish to brown augite and a fair quantity of magnetite or ilmenite. Considerable alteration of much of the augite has occurred with the development of calcite and the introduction of some chlorite. In the interstices of the rock some of the felspar is somewhat spherulitic. The rock is a fine-grained felspathic dolerite.

1729. A rather large mass probably intrusive into the Middle Devonian, south of Ostler's, on the Mitchell River.

In hand specimen the rock is of medium grain size, and dark grey green in colour. Under the microscope the texture is between the hypabyssal and the plutonic. There is a tendency for the irregularly quadrate felspars, oligoclase to andesine, to be porphyritic. The ferromagnesian mineral, originally hornblende, is now largely pale green and fibrous in habit, and is largely chlorite. A small amount of minute felspars with interstitial quartz, constitutes a second generation of crystals in which are recognised small magnetite phenocrysts and occasional irregular crystals of sphene. The rock is a diorite porphyrite.

1731. Big dyke 150′ thick, striking N.40°E., penetrating Middle Devonian, west of Loc. 7.

In hand specimen the rock is a nearly black, fine-grained rock, showing minute quartz and specks of pyrites. Under the microscope its fine-grained texture is clear, but the rock is much altered, both plagioclase and augite being largely altered. The lath-shaped plagioclase still shows twinning, but the ferromagnesian mineral is now changed to chlorite. A little interstitial quartz, and a small amount of black opaque iron ores occur; calcite is moderately abundant. The rock is a fine-grained quartz dolerite.

1732. Dyke 15′ thick, cutting Middle Devonian, south end of Whitbourne's paddock, Sandy's Creek.

In hand specimen the rock is black, fine-grained, but crystalline, with small porphyritic felspars. Under the microscope the rock is clearly porphyritic. Clear large lath-shaped labradorite felspar and pale brown augite phenocrysts are set in a finer textured ophitic aggregate of the same minerals, with the addition of granular magnetite; green chlorite and calcite, are noted as secondary products. The rock is a porphyritic dolerite.

1612. Sill or interbedded flow in Middle Devonian five chains south of south end of Whitbourne's flat, Sandy's Creek.

In hand specimen the rock is dark, fine-grained, and somewhat decomposed. Under the microscope it is seen to be considerably altered. Phenocrysts of altered plagioclase and hornblende altered to chlorite are abundant. A fair amount of granular magnetite is present and the felspathic groundmass contains a little interstitial quartz. The rock is an altered porphyrite.

1745. Acid lava at base of Upper Devonian, ridge south of Ostler's, and south of the Mitchell River.

In hand specimen the rock is compact, fine-grained, pink to grey coloured, showing fluidal banding. Under the microscope the fluxion structure is well developed. Phenocrysts of corroded quartz crystals are set in a microcrystalline to cryptocrystalline groundmass of quartz and felspar in which dark irregular bands are developed streaming past and round the phenocrysts. The rock is a banded and fluidal rhyolite.

1740. A nodular or spherulitic lava at the base of the Upper Devonian, ridge south of Ostler's, and south of the Mitchell River.

In hand specimen large nodular spherulites up to 1½ inches diameter of dense brown material, with lighter margin, are set in a dense fine-grained matrix. Under the microscope the section passes through the margin of one of the nodules, which is brown in colour and almost completely glassy. The nodules are set in a rock which shows a remarkable flow structure of cryptocrystalline to glassy texture, in which occur small phenocrysts of corroded quartz and of felspar. The rock is a spherulitic or nodular rhyolite.

Summary and Conclusions.

The earlier work of Howitt and others in the Tabberabbera district is referred to. The conditions of access to the district have been improved by the making of good roads to the area, but within the area the diminution of settlement due to decay of mining and introduction of rabbits has led to the overgrowing of tracks, the growth of secondary scrub and the blackberry pest; and these combine with the rugged topography to make geological work difficult. Two periods of three weeks each in January and February of 1924 and 1925 were spent in the area, which lies 40 miles NNW. of Bairnsdale in Eastern Victoria. The boundaries of the geological formations are approximately located on the map published with this paper, and the structure elucidated by three sketch geological sections. The area of Upper Ordovician rocks, consisting of black shales, cherts and sandstone, previously known in Sandy's Creek has been extended.

It has been shown that at Tabberabbera itself, formerly regarded as the type area for the Tabberabbera shales of Middle Devonian age, no Middle Devonian rocks occur, but that a broad belt of Silurian rocks, consisting of impure limestones, shales, grits, sandstones and conglomerates, trends NNW. to SSE. across the area, including Tabberabbera. The Middle Devonian rocks, consisting of blue limestones, shales and sandstones, with characteristic fossils such as *Spirifer yassensis*, are restricted to the western part of the area.

The Upper Devonian rocks, red and purple sandstones, shales and conglomerates, with interbedded rhyolites, form an unconformable plaster in the central part of the area, resting in turn on the denuded edges of Middle Devonian, Silurian and Upper Ordovician rocks. The Ordovician, Silurian and Middle Devonian rocks have suffered from very severe compressive earth movements, and are in consequence highly folded, even the Middle Devonian showing dips ranging from 45° to 80° on either side of the fold axes. The boundaries between these formations are determined by unconformities or faults. The Upper Devonian rocks, with a dip of 5° to the SW., have not been compressed into folds, but were elevated and tilted with the older rocks by late Kainozoic differential earth movements. The Mitchell and Wentworth Rivers have cut steep valleys and gorges, and have given an immature topography to the district.

The outstanding structural features in the Tabberabbera district are the local character of the severe compression of the Middle Devonian sediments, contrasted with their open folding at Buchan and Bindi, and the gigantic character of the unconformity separating them from the Upper Devonian rocks. The appreciation of this has led to the discussion of the age of the rocks called Upper Devonian, from which no fossils have been obtained in this district. The comparison with areas of similar rocks at Iguana Creek, the Avon River, Mt. Wellington and Mansfield in Victoria, and Mt. Lambie and other areas in New South Wales, has led to the view that the reference of them to the Upper Devonian can be justified on the available evidence.

A brief account of the petrology of the igneous rocks of the area is appended. Lava flows of spherulitic and of banded rhyolite are interbedded with the Upper Devonian. It is shown that numerous dykes penetrate the Ordovician, Silurian and Middle Devonian rocks, and that a few have been noted by Mr. Easton penetrating the Upper Devonian. The types include mica lamprophyres, hornblende porphyrites, felspar porphyrites, keratophyres, quartz keratophyres, spherulitic quartz porphyrites, dolerites and oligoclase trachytes. In addition four examples of felspathoid-bearing rocks, tinguaites, have been recorded, two as boulders and two as dykes "*in situ*."

It is shown that the Eastern part of Victoria constitutes an alkali-rich province, since felspathoid-bearing rocks have been previously recorded by the author from Pretty Boy Pinch, the Tolmie Ranges, Mt. St. Bernard and from Omeo, localities lying west, north-west, north and north-east of Tabberabbera.

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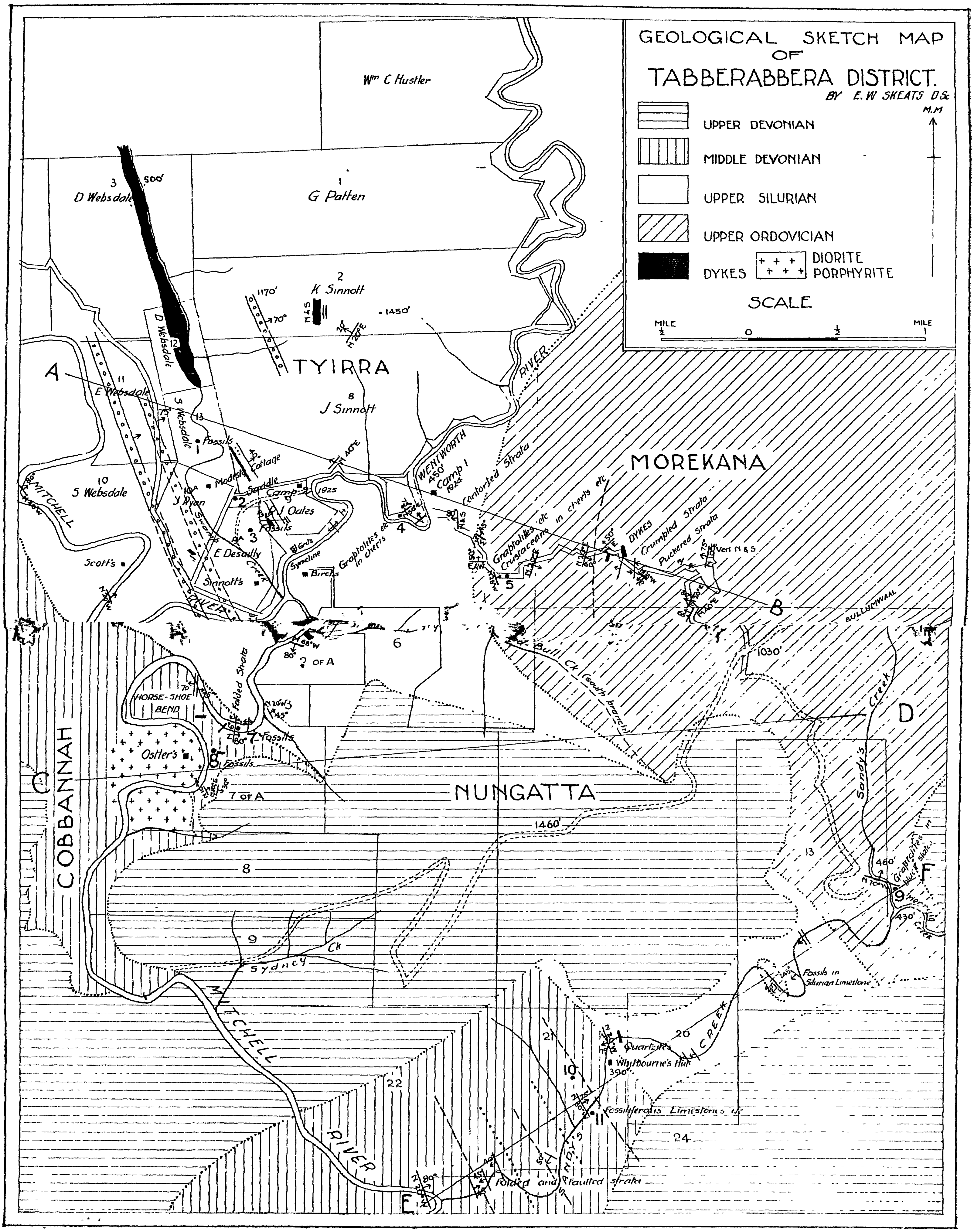
GEOLOGICAL SKETCH MAP OF TABBERABBERA DISTRICT.
BY E. W SKEATS D.Sc
UPPER DEVONIAN
MIDDLE DEVONIAN
UPPER SILURIAN
UPPER ORDOVICIAN
DYKES
DIORITE PORPHYRITE
SCALE
MILE ½ 0 ½ MILE 1
M.M
TYIRRA
MOREKANA
NUNGATTA
COBBANNAH
Wm C Hustler
G Patten
D Websdale
K Sinnott
J Sinnott
E Websdale
S Websdale
J Ryan
E Desailly
J Oates
Scott's
Sinnott's
Birch's
Ostler's
Whybourne's Hut
MITCHELL RIVER
WENTWORTH RIVER
Bull Ck (south branch)
Sandy's Creek
Sydney Ck
HORSE-SHOE BEND
Graptolites etc in cherts
Contorted Strata
Crumpled Strata
Puckered Strata
Folded Strata
Folded and Faulted strata
Fossils in Silurian Limestone
Fossiliferous Limestone
Quartzites
Syncline
Camp 1 1924
Saddle Camp 1925
Modesty Cottage
BULLUMWAAL
A
B
C
D
E
F

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ART. IX.—*The Building Stones of Victoria, Part II. The Igneous Rocks.*

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(With Plate XVI)

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Introduction.

In the following paper some Victorian igneous rocks used as building stones are described. Of the fourteen rocks included here, twelve have been used for constructional or ornamental purposes as well as in monumental masons' work, and one in monumental work alone, and one, the Tynong granite, has recently been selected for use in the Victorian Shrine of Remembrance.

H. C. Richards (13) in 1909 published a description of eight Victorian sandstones used as building stones. The title of his paper was "The Building Stones of Victoria—Part I.: The Sandstones." Therefore, this paper is styled "The Building Stones of Victoria, Part II.: The Igneous Rocks."

In addition to the building stones described here, there are other igneous rocks occurring in Victoria which have been used in the past for building stones, and of course many others which may be used in the future, but so far as the writer is aware those referred to here include most of those being quarried at the present time for purposes of building.

From Victorian igneous rocks entire buildings have been erected, or they have served as basecourses, as ornamental pillars or columns, and for monumental works, and at the present time thin slabs are frequently cut for use as a veneer on concrete buildings.

Igneous rocks used as building stones are divided into three classes by stonemasons. The first is that of the "granites," which in this connection includes all coarse, even-grained types of igneous rocks, and these are usually capable of taking a polish. The second is the "porphyry" class, including all rocks with large porphyritic felspar crystals. As a rule, these are used in small polished slabs for ornamental purposes. The "bluestones" or basalts form the third class. These are sombre, blue-grey coloured fine-grained rocks, whose chief use as building stones is for basecourses, where their dark colour makes an effective contrast with a lighter coloured main structure.

The following scheme has been adopted in the description of each building stone. In an introductory paragraph the site of the quarry, the amount of stone available there, and the systems of jointing with their corollary, the size of blocks obtainable, are described. In a paragraph headed "Appearance," the colour and structure of the stone are referred to as well as any blemishes it may possess. Under "Working Qualities," the ease of sawing and polishing the stone and the quality of its polish are treated. Following this, all the tests done on each stone are grouped together, and in a final paragraph a tabulation of some of the buildings erected of the stone is given, with a summary of the principal characters which either recommend or forbid its use.

The rocks are described in the order of the classes recognised by technical workers in the trade. Within each class, where there is more than one representative, that stone most in use for building is treated first, and is followed by the rocks in descending order of their use up to the present time.

Of the quarries described here all have been visited by the writer, with the exception of those at Gabo Island and Tallangatta. All crushing strength tests except that of the Gabo Island granite have been carried out in the Melbourne University Engineering School, on test pieces, most of which have been prepared by the writer. The remaining tests have been done by the writer unless the contrary is stated.

The writer desires to acknowledge gratefully the helpful advice and criticism offered to her throughout this work by Professor Skeats, and to thank Associate-Professor Summers also for his continuous assistance.

Messrs. William Train and Co., and the owners and managers of the various quarries visited, have been always most courteous in throwing open their works for inspection, and in giving much practical advice.

Previous Literature.

In 1860 a committee of the Royal Society of Victoria published a report of building materials (1) occurring in Victoria. The report which, so far as is known, is the first record in print of such occurrences, describes rather fully the basalt or "bluestone"

of the colony, without, however, specifying localities from which it was then obtained. It records various quarries for granite, indicating that stone for building in Melbourne had been obtained at that period from Gellibrand's Hill, at Broadmeadows, and from Gabo Island.

In 1864 a treatise on "Australian Building Stones," by J. G. Knight (2), was published in London. As the author was the chairman of the Committee of the Royal Society referred to above, this treatise contains in a fuller form practically the same information given in the Committee's Report.

Later reports are confined to lists of localities of quarries in granite, greenstone, basalt, serpentine, etc., until in 1915 R. T. Baker published the "Building and Ornamental Stones of Australia" (17), which includes notes on many of the igneous rocks of Victoria, referring to their use or possible use as building stones. A similar list, though a shorter one, appears in the Commonwealth Year Book for 1909 (18). Until the present time the only other references have been reports in Geological Survey Records on single quarries and a few references in reports on the building stones of other States.

Publications dealing with the use or possibilities of Victorian igneous rocks as building stones as well as other books and papers referred to here are listed in the bibliography at the end of the paper.

The Igneous Building Stones of Victoria.

Granites.

The "granite" of the worker in the stone trade has been defined above as a coarse, even-grained type of igneous rock which can usually be polished. This group of rocks is subdivided according to the predominating colour of each type into red or pink, grey, green and black granites. In a red or pink granite the felspar present is usually orthoclase or an alkali plagioclase which has become reddish brown by iron staining. This felspar being present in comparatively large proportion, imparts its reddish brown colour to the whole rock. These "red or pink granites" conform most nearly to the granite of the petrologist. In a grey granite the felspar present is a white one uncoloured by iron, which occurs with small amounts of black mica, giving a "pepper and salt" or grey colour to the stone. The petrologist's granodiorite is included here. The green granites derive their colour from the minerals hornblende and epidote. The latter of these occurs as an alteration production of plagioclase felspar. Such rocks are diorites. A black "granite" may be composed of orthoclase or plagioclase felspar, augite and biotite, with an iron oxide, when it will fall into either the syenite or diorite petrological class. With the addition of olivine and the subtraction of some of the felspar, the rock becomes a gabbro. The combined effect of

these minerals approximates to a black stone. The first two classes include a far greater proportion of rocks than do the last two.

In addition to this subdivision by colour, granites are classified according to their grain size. A convenient method of classification is outlined by T. Nelson Dale (10). By it a granite containing felspars of more than 1 centimetre (2/5 inch) diameter is classed as coarse-grained, one with felspar whose diameters lie between 0·5 cm. (1/5 inch) and 1 cm. (2/5 inch), is medium grained, and all those with felspars below 0·5 cm. are fine-grained. Throughout this paper this scale is referred to when the terms coarse-grained, medium-grained, and fine-grained are used. The lower limit for the coarse-grained division seems rather a high one, but since this is the most distinctly enunciated scale of grain size, and is quoted by J. Allen Howe in the "Geology of Building Stones" (15), it has been adopted here.

In the quarrying of granite the system of joints which occur in the rock are important. In most granite quarries it is found that the rock will split most easily in one definite direction, which is known always as the "rift." In a direction at right angles to the rift a granite will also split with ease, but slightly less well than along the rift. This second direction of splitting is known as the "grain." The terms "rift" and "grain" are used throughout this paper with the same significance. In most quarries the rift and grain are vertical, and the joint system in the third dimension is usually horizontal, so that a sheet-like structure in the granite is suggested. This third joint is never so perfect as either rift or grain, the break being usually concave or convex, and the "sheets" more or less lens-shaped.

Another term of almost universal application in quarries, which needs explanation, is the word "dry." A "dry" is a direction in a rock mass along which a block of the stone tends to fracture, but may not do so until after it has been quarried and exposed for some time. The fracture does not usually take place along a plane, but along a curved direction and penetrates for but a short distance into a block. "Drys" are spaced quite irregularly, and their existence in a block of stone is often not suspected until after cutting and dressing is completed, when if a "dry" shows up the block must be rejected.

Harcourt Granite.

The granite used most widely in Victoria as a building stone outcrops over an area of some 150 square miles in the neighbourhood of Harcourt and Ravenswood, 80 miles north of Melbourne and 20 miles south of Bendigo. It is quarried on the side of Mount Alexander, three miles east of the Harcourt railway station, on the Melbourne to Bendigo line, where quarrying commenced over sixty years ago, and during this period a large quantity of stone has been removed.

The joint system in this rock mass is exceedingly favourable for the extraction of large blocks. The "rift" or easiest direction of splitting the stone runs vertically north and south, and the "grain" is also vertical, and runs east and west. Rift and grain are so spaced that very large blocks can be obtained; in 1921 a block 84 feet long, 28 feet wide and 25 feet deep, which weighed 5000 tons was moved by a single charge of powder.

Appearance.—This granite is a light grey one, containing large crystals of white felspar and glassy quartz, and a smaller quantity of biotite mica. The felspars average 1/5 inch in diameter, so that the granite just falls within the medium-grained division of the Nelson Dale scale. The grain size is very even through the rock except where "black spots" or "heathen" occur. These are patches of dark fine-grained material averaging two square inches in size, although much larger ones occur. They are rich in the mineral biotite, and form basic segregations. They show prominently on sawn and polished blocks and occur at an average distance apart of two feet. Less frequently small acid veins about half an inch wide occur, which contain quartz and felspar alone. These are not very noticeable on account of the prevailing light grey colour of this stone. Its light grey colour is this granite's most noticeable feature, and is especially marked on smooth, unpolished blocks. The polished stone has a darker colour, which becomes somewhat lighter after exposure, apparently on account of the gradual evaporation of quarry damp. The granite placed in 1926 in the additions to the State Savings Bank in Elizabeth Street was distinctly darker at first than that in the first part of the building erected in 1911, but now the junction between the two cannot be distinguished. Specimens from all parts of the quarry are very similar, and it is noticeable that the rock outcropping at Big Hill, ten miles to the north of this quarry, does not differ in grain size nor mineral composition.

Working Qualities.—Rift and grain in this granite are so well developed as to make the ease of working this stone at the quarry a standard of excellence among granite masons. Blocks of all sizes and shapes required are obtainable, and since the supply is practically inexhaustible any type of work can be undertaken in this stone. At the mason's yard this stone takes a good edge or "arris," and it polishes well, although biotite is inclined to flake off from the surface, leaving it uneven.

Resistance to Crushing.—This stone has been tested in the Melbourne University Engineering School three times for its resistance to a crushing stress. Three inch cubes were used for the tests, which were conducted on the dry stone. The cubes crushed at 11,444 lbs. per sq. in. (736 tons per sq. ft.), 11,333 lbs. per sq. in. (728 tons per sq. ft.), and 8510 lbs. per sq. in. (547 tons per sq. ft.) respectively. The stone has a somewhat lower crushing strength than most of the granites described here.

Absorption.—The percentage of water absorbed was determined by immersing a small weighed and dried block of the stone in water. The rectangular shape of the block made the conditions approximate to those experienced by the stone in a building in wet weather. After four days' immersion the block absorbed 0·11% of its weight of water, so that Harcourt granite may be called impervious for all practical purposes.

Chemical Analysis.—A chemical analysis of this rock has been made by Mr. G. Ampt, and the result published in a paper by Dr. H. S. Summers (16). It is included here under Chemical Analyses at the end of the paper.

Specific Gravity and Weight per cubic foot.—The specific gravity of this granite is 2·678, and hence the weight of a cubic foot is 167·5 lbs., which is a normal weight for a granitic rock.

Microscopic Examination.—A thin section of this rock shows idiomorphic crystals of felspars, interstitial quartz, in some cases under strain, and highly pleochroic biotite. There are a few occurrences of the accessory minerals apatite, zircon and magnetite. The relative grain size has been calculated for the three principal constituents by an adaptation of Rosiwal's method for measuring the dimensions of minerals (7). This rock is coarse-grained enough for the measurements to be made in millimetres on the polished surface of the rock itself. The result of twelve traverses gave the ratio Quartz: Felspar: Biotite, as 4: 5: 2.

Felspar is in the form of plagioclase and orthoclase in the proportion of 3: 2. The plagioclase was determined as Ab_1An_1, or $Na_2O\,CaO.2Al_2O_3.8SiO_2$ by measurement of its angle of extinction. Orthoclase has altered to kaolin, which has become iron-stained, and some of the plagioclase has changed to epidote. This rock belongs to the adamellite class, since more than one-third and less than two-thirds of the felspar is orthoclase. In the American Classification the rock falls into Class 1, Persalane; Order 4, Brittanare; Rang 2, Toscanase; Subrang 3, Toscanose.

A portion of a basic segregation was examined under the microscope. It is distinctly fine-grained. Plagioclase is more abundant than orthoclase and the former shows marked alteration to epidote. The section is crowded with small, stumpy biotite crystals in greater abundance than in the normal rock. Quartz is also present. This section was difficult to obtain since the basic segregations are crumbly.

Uses.—This granite is widely used in Melbourne. Some of the better known buildings in which it appears are the Colonial Mutual Life Assurance, formerly the Equitable Life Assurance, where the upper storeys have been constructed of smooth, unpolished blocks, the Commercial Travellers' Club, the State Savings Bank, the Herald Newspaper Office, the Union Bank, the Flinders Street Railway Station, and many others. The stone is seen throughout the city in polished ornamental panels, pillars, steps and basecourses.

Its very light grey colour must be regarded as a defect in this stone, because it becomes dirty rapidly in a city atmosphere. The gateway of the Fish Market in Flinders Street, and Rocke, Tompsitt's warehouse in the same street are examples of dirty Harcourt stone.

The dark basic segregations or "heathen" are a disfigurement. These may be seen in the wall of the head office of the State Savings Bank.

No other granite, either Victorian or imported, has been used to the same extent as this stone for building, ornamental and monumental purposes in Melbourne.

Wangaratta Granite.

Granite from this district has been used locally and in Melbourne. It is quarried in the Warby Ranges, about seven miles SW. of Wangaratta. The Warby Ranges consist of a granite inlier rising abruptly from a plain composed of Recent material.

The quarry for building stone has been made in an area where segregation of pyrites has occurred in the granite, giving it an appearance distinctly different from that of the pyrites-free granite found at no great distance. The quarry is on a hillside, and after the blocks are dislodged and shaped into roughly rectangular blocks they are rolled downhill and levered on to lorries. The working face slopes nearly parallel with the slope of the hillside. This quarry face is very uneven, since there is trace neither of rift nor of grain in the granite, but "drys," whose nature is defined above, are found irregularly through the stone. On account of the "drys," the size of the blocks obtainable is very uncertain, and a great deal of material has to be rejected. Blocks up to six feet in length have been got out, but there is no guarantee that blocks of this size can be secured frequently. The size more usually obtained is 2 ft. 6 in. long by 1 ft. square. This lack of regular jointing somewhat restricts the use of this granite as a building stone.

Appearance.—The granite is pink and even-grained, but its appearance varies with the amount of pyrites present, and the proportion of this mineral which has been oxidised. Three distinct types can be recognised, and are described here as A, B and C.

Type A is a pale pink, fine-grained granitic rock, containing abundant creamy felspar, averaging 1/20 inch in diameter, grains of quartz, and scattered pyrite cubes. Some of these have been lost, leaving small cavities in the rock.

Type B is a very soft friable cream-coloured rock. It contains felspar, kaolin, quartz, but no pyrites, and is very porous.

Type C is a dark, fine-grained stone, of a colour ranging from pale pink to purple. Felspar is very abundant, and there is a good deal of quartz. Pyrites is absent, though occasionally cubic cavities, which contained originally pyrites crystals, are to be seen.

Limonite resulting from the oxidation of the sulphide mineral has penetrated the felspar, colouring it dark pink and purple, and probably causing the greater hardness of this type. Type C has a warm and attractive appearance on either smooth or rock-faced surfaces due to the alternating red and cream patches, according to the varying richness of the stone in ferric oxide.

Working Qualities.—The buildings in which this stone has been used have been constructed of comparatively small blocks, averaging 2 feet 6 inches by 1 foot square. Types A, B and C have been used for slightly different purposes in building construction. Type A, rich in unaltered pyrites, is used with a rock-faced finish in the construction of walls. Men who have worked on both say that this stone may be worked with about the same ease as Melbourne basalt. When it is being chiselled a strong smell of sulphur dioxide is noticed. It will not work up to a particularly sharp arris. Type B being a soft stone is very easy to work, and is used with the axed finish required in window surrounds. Type C, the hardest stone, is selected for rock-faced work, and is used chiefly in walls and foundations.

The rock rich in pyrites (type A) was found to take a good polish; square cross-sections of pyrites, prismatic crystals of cream felspar and quartz grains showing up well against a pale pink groundmass. The only undesirable feature is the presence of some small pits on the surface. Type C, which is coloured purple-red, is much too porous to look well when polished, though the solid parts take a high polish. Holes 1/8th in. in diameter and 1/16th in. deep are commonly seen.

Resistance to Crushing.—Specimens of types A, B and C were tested for their resistance to crushing. Type A, which is the stone containing unaltered pyrites crystals, is much the strongest of the three, since it broke only under a load of 19,600 lbs. per sq. in. (1261 tons per sq. ft.). Type B, the soft stone, fractured under a load of 7,110 lbs. per sq. in. (457 tons per sq. ft.), which is a low value for the crushing strength of any igneous rock. Type C proved rather stronger, breaking beneath a load of 9,670 lbs. per sq. in. (622 tons per sq. ft.). The comparative weakness under a crushing load of the two latter stones compared with normal igneous rocks can be attributed to the changes suffered by the stone in the oxidation of its pyrites. The figures indicate, however, that even these two stones are quite strong enough for use for ordinary purposes in a building.

Absorption Percentage.—Rectangular blocks of all the stones were tested for their absorption percentages. They were immersed in distilled water until they ceased to gain in weight, when they were judged to be completely saturated. This took a different period for each stone. All their absorption percentages are above the average of normal granitic types, due to the cavities left, when pyrites cubes are lost, and the general alteration suffered by the stones.

Type A immersed for 9 days gained 1·45% of its weight.
„ B „ „ 13 „ „ 3·75% „ „
„ C „ „ 14 „ „ 4·08% „ „

Specific Gravity and Weight per Cubic Foot.—Type A has a specific gravity of 2·512, and weighs 157 lbs. per cubic foot. Type B weighs 145 lbs. per cubic foot and its specific gravity is 2·324. The specific gravity of type C is 2·446, and its weight per cubic foot is 152·5 lbs.

These figures are all low, which is probably due to the fact that the stones are rather porous. The resulting low weight per cubic foot is a factor in favour of the use of this stone.

Microscopic Examination.—In a thin section of type A, felspar makes up two-thirds of the rock, quartz bulks largely, and there are some cubic crystals of pyrites. The felspar is allotriomorphic, much of it being clouded by formation of kaolin, which is stained by ferric oxide. Epidote and sericite have formed also, and some of the unaltered felspar shows lamellar twinning. Kaolin is formed typically from alkalic felspar, while sericite and epidote come from calcic plagioclase, and since a greater proportion of the felspar present has altered to ironstained kaolin than to epidote and sericite, this rock may be termed an altered granite.

Type B is very similar to type A, except that fresh, unaltered pyrites cubes are absent from B. Clouded felspar is the most abundant mineral. Kaolinization and limonitic staining are marked, and the development of sericite from plagioclase is more noticeable than in type A.

A thin section of type C is distinguished from types A and B by the greater abundance of hematite present. After its formation by oxidation from pyrites, the hematite penetrated along cleavage cracks of the kaolinized felspar, making a rectangular network within the mineral (Pl. XVI., Fig. 1), which has strengthened and hardened the stone. Little quartz is present, and no unaltered pyrites.

Uses.—The stone has been used in two churches in Wangaratta. The first part of the Anglican Cathedral was built about 1908 of stone from this quarry, and in 1922 the quarry was reopened to obtain stone for additions to this building. Blocks of the hard red material (type C) are used with a rock-faced finish in the main structure, while the softer type B is used for the window surrounds. Rock was extracted from this quarry 60 years ago, when blocks for the Catholic Church in Wangaratta were obtained. In Melbourne sawn blocks of Wangaratta granite have been used in Collins House, Collins Street. The stone used appears most like type C. For the keystone of the arch over the entrance a block of Sydney sandstone was introduced.

The blocks are light reddish in colour, and show patches of a darker colour due to the oxidation and leaching of iron of the pyrites crystals originally contained in the rock. Such differential staining is more usually associated with sedimentary rocks, and the rock in this building is often mistaken for such.

The warm reddish colour of this stone is very attractive, and should make it a popular one for city use, since it discolours less readily after exposure to a city atmosphere than do stones of paler tints.

Cape Woolamai Granite.

The granite outcrop of Cape Woolamai forms the south-eastern point of Phillip Island in Westernport Bay, and has provided stone for building in Melbourne. Cape Woolamai is two miles across Newhaven Strait from San Remo, a township on the mainland 80 miles by road and rail south-west of Melbourne. By another route the granite may be taken about 15 miles by water to Stony Point, which is 46 miles from the city by rail. The distance from Cape Woolamai to Melbourne directly by water is approximately 65 miles. The depth of water at the stone landing stage at the Cape is 2 fathoms. Three hundred yards out it has increased to 12 fathoms.

The Cape is formed of a granite cliff, rising out of the sea to a height of about 300 feet. At its widest, the Cape is one mile across, and the granite is nowhere covered by more than a few inches of unconsolidated sands. From the headland a jetty of granite blocks was built out into Westernport, from which boats removed the stone. At present the main quarry, which is connected to this jetty by a tramline somewhat out of repair, is under water at high tide. The perpendicular sides of this disused quarry show that large well-shaped blocks were obtained by fracture along regular joint planes, one of which strikes north and south with the face of the joint plane dipping 60° to the east, while the second strikes east and west and dips 30° south. Blocks up to 6 ft. in length by 2 ft. square are still lying at the stone landing stage, while pillars 12 ft. high by 2 ft. square, and blocks 7 ft. long by 3 ft. 6 in. wide by 2 ft. 6 in. high, were used in the base-courses and portico of the Equitable Building, now the Colonial Mutual Life Assurance Building.

The granite mass contains cream-coloured acid veins and vughs of large pink felspar crystals, which mar the evenness of grain of the rock. Segregations of basic material do not commonly occur in this stone, which is remarkably free from any dark mineral.

Appearance.—This granite has a pleasant colour varying between a light and a dark pink, according to the amount of alteration suffered by the felspar present. The felspar crystals average three-tenths of an inch in diameter, so that the grain size of the rock is medium. It is composed mainly of pink felspar and quartz. In addition a little green-stained felspar and a subordinate amount of black mica are present.

The granite when polished has a darker colour, and makes a handsome ornamental stone. Narrow veins about 2 inches wide, containing large quartz and felspar crystals from 1 inch to 2 inches in length, cut across blocks of the normal coarse-grained granite. More rarely portions of the stone are marred by dark

streaks caused by the segregation of ferromagnesian minerals in narrow veins. Some of these can be seen in the base-course of the Equitable Building. One vein measures 18 inches long and 2 inches wide. These veins are not so dark-coloured as the "black spots" in Harcourt granite, because the black minerals are not so closely packed, and therefore are less of a disfigurement to the stone.

Working Qualities.—Little is known of other working qualities than the polish of this stone, because it is over 30 years since it was worked. On a test piece in the laboratory a surface was smoothed and an extremely fine polish was obtained with relatively little work.

Resistance to Crushing.—This granite has a remarkably high crushing strength for a rock of this grain size. A block measuring approximately $1\frac{1}{2}$ sq. in. by 2 in. broke under a load of 27,100 lbs. per sq. in. (1743 tons per sq. ft.).

Absorption Percentage.—A smooth block of this granite was immersed in distilled water for 12 days, during which time it absorbed only 0·18% of its weight of water.

Chemical Analysis.—The result of a chemical analysis of this rock, which has been carried out by Mr. A. G. Hall for Dr. H. S. Summers (16), appears at the end of this paper. This granite is the richest in silica of the eight granites and granodiorites, whose analyses are published in the paper cited.

Specific Gravity and Weight per Cubic Foot.—The weight per cubic foot of this stone is 165 lbs., calculated from the specific gravity of 2 643, given with the chemical analysis (16).

Microscopic Examination.—The minerals present are felspar, quartz, biotite, apatite and zircon. Felspar is in the form of microperthite altered to kaolin, and of plagioclase near oligoclase. Some microperthite crystals show a thin film of iron oxide, which is the cause of the reddish tint seen in most of the felspar in hand-specimens. The tinge of green seen in others is due to small crystals of epidote, formed from plagioclase. Large grains of quartz are abundant, while flakes of biotite in a dark-coloured, corroded form are rare. Some of these are altered to chlorite. Apatite and zircon are included in mica. The proportion of orthoclase to plagioclase is greater than 2 to 1; therefore this rock is a true granite.

Uses.—Large polished blocks (7 ft. long by 3 ft. 6 in. wide by 2 ft. 6 in. high) form the base-course of the Colonial Mutual Life Building, and pillars 12 ft. high flank the entrance. This was built for the Equitable Life Assurance Company in 1893, and the Cape Woolamai quarry was opened to supply stone for this building. So far as is known, it is used nowhere else in the city. Vertical cracks have developed across the face of some blocks. It is likely that these have arisen from "drys" in the granite, while the appearance of some blocks is marred by quartz veins. It is reported that specks of gold can be seen on some of the polished blocks.

The size of blocks obtainable, the excellent polish and colour of this granite are in its favour, and though the quarry is rather inaccessible, its position at the water's edge makes possible direct water transport to the city by boats of shallow draught.

Gabo Island Granite.

This small island is composed of granite, which has been quarried and used for building. It is close to the coast near the boundary between Victoria and New South Wales, and lies near the sea route between Sydney and Melbourne, 242 miles from the former and 333 from the latter. It is thus accessible by boat from either capital. Admiralty charts record the depth at the jetty as 5 fathoms. Blocks measuring 2 feet high by 3 feet square are in use.

Appearance.—The presence of abundant red felspar gives an attractive pink colour to this rock. It is composed of comparatively small crystals, all uniform in size. Since the felspars have an average length of one-tenth of an inch, the rock falls into the fine-grained group of building stones. In a polished block the colour is dark pink, though rectangular pale green felspars frequently occur. The dark red colour of rock-faced blocks of this stone can be seen in the Elizabeth Street Post Office, Melbourne. A vein, half an inch wide, of very fine grained quartz and pink felspar crosses one of the hand-specimens examined.

Working Qualities.—Blocks of this stone have been left exposed for 60 years in a stonemason's yard in Melbourne. They have retained a good " arris " and polish until the present time.

The granite polishes fairly well, although small pits are left on the surface where hornblende has been torn out while the stone was being ground smooth.

Resistance to Crushing.—The result of crushing strength tests on this granite is published by Baker and Nangle (12). Three 3-inch cubes were tested and their strengths in lbs. per sq. in. were 15,200, 14,900, and 17,500 respectively (979, 950, and 1128 tons per sq. ft.).

Absorption Percentage.—A small block of the stone dressed to a rectangular shape was immersed in distilled water for eight days, when it was found to have increased in weight by 0·39%.

Chemical Analysis.—The chemical analysis is recorded at the end of the paper.

Specific Gravity and Weight per Cubic Foot.—The weight per cubic foot of this granite is slightly under 165 lbs., calculated from the specific gravity (16), which is 2·635.

Fire Test.—Baker and Nangle (12) have carried out tests to discover the effect of heating and sudden cooling by streams of water on Gabo Island granite. These tests imitate the effect of fire and fire-fighting apparatus on a granite building. A cube was heated gradually to 783°C., and removed after 35 minutes, when it was found to be badly cracked. A second cube was heated

gradually to 544°C. and plunged suddenly into cold water. This cube was almost unaffected.

Microscopic Examination.—This granite contains altered felspar, abundant quartz and altered hornblende. Most of the felspar is in the form of a microperthitic intergrowth beneath a film of iron-stained kaolin, while some of it shows lamellar twinning and a cloud of alteration products (epidote, sericite, etc.), in which are caught up many small flakes of chlorite, which is the cause of the green felspar noticed in the hand specimen. Ilmenite and apatite also occur. The rock is best described as a normal granite.

Uses.—Polished columns of this granite are used in the building of the Australian Travel Service, 493 Collins Street, rock-faced blocks of the stone support Tasmanian sandstone columns in the Elizabeth Street Post Office, and smooth-dressed blocks form the base-course of the Customs House, Flinders Street.

The colour of this stone readily recommends its use, and its strength is great enough to fulfil any requirement. Unfortunately, the long distance of Gabo Island from a city will operate against the frequent use of the granite from there.

Orbost Granite.

About two miles east of Orbost, on the road to Mallacoota Inlet, and 233 miles east of Melbourne, Young's Creek has exposed a large face of granite which was quarried for use in the Commonwealth Bank in Melbourne in 1923. No soil overburden covers the granite, and there is an exposure about 40 feet high by 60 feet in width. The face of stone in the quarry is remarkably irregular, and shows more or less conchoidal breaks, which prove that there is no continuity in the jointing system in the stone. The most marked joint runs on a sloping plane at right angles to the face of the quarry, but is not continuous for any distance.

Appearance.—This is a greenish-grey granite, considerably darker in colour than the Harcourt stone. Its green tint comes from stained felspar, and is an attractive colour, especially when seen on a polished block. The felspars average one-tenth of an inch in diameter, and the granite is therefore fine-grained.

The granite mass is traversed by many veins of quartz up to an inch in width, with some of which epidote and carbonate minerals are associated. Large, dark-coloured segregations of basic minerals, and narrow veins of dark-coloured minerals, also mar the appearance of the stone, and in addition blocks up to 12 inches square of fine-grained sedimentary material occur as inclusions. Some of these are surrounded by a rim of partially absorbed material. Even small hand specimens cannot be obtained free from disfiguring "black spots." One block of stone outcropping near the quarry is traversed by three narrow dark veins, one of which on examination under the microscope was found to consist of a string of chlorite crystals altered from hornblende and biotite. The minerals from which the string of chlorite has been derived

have resisted weathering to a greater degree than has the remainder of the rock, with the result that the narrow dark veins are the centres of three ridges standing about one inch above the general surface of the rock.

Working Qualities.—This stone was cut into two 2-inch cubical blocks for testing purposes, and it was noticeably easier to saw than most other granitic types, presumably on account of decomposition suffered by the minerals present. The stone polishes rather well, though the polished surface is somewhat pitted. These pits are due to the loss of biotite during the grinding of the rock.

Resistance to Crushing.—Two rectangular blocks each approximately a two inch cube of this granite were tested. One crushed beneath a load of 15,300 lbs. per sq. in. (984 tons per sq. ft.), while the other did not crush under the heaviest load of which the machine is capable, 100,000 lbs., or 25,400 lbs. per sq. in. (1633 tons per sq. ft.). It was noticed that although the specimen had not actually broken, it was just on the point of breaking. It should be pointed out that although the crushing strengths of these two cubes vary rather widely, they were prepared in a similar manner by the writer from a single block of the stone, and were crushed in the same machine by the same operator on the same day.

Absorption Percentage.—A smoothed block of Orbost granite absorbed 0·15% of its weight of distilled water after immersion for eight days.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this stone is 2·803, hence the weight per cubic foot is 175 lbs.

Microscopic Examination.—A thin section shows quartz in allotriomorphic and interstitial grains and felspar in relatively small idiomorphic crystals, which are altered considerably, though in a few crystals the lamellar twinning of the plagioclases can be detected. The plagioclase has been saussuritized, causing the formation of grains of zoisite, a little epidote and small, brightly polarizing fibres of mica, probably the soda mica, paragonite, since it has developed from plagioclase. Biotite is present, showing very extensive alteration to chlorite, which imparts a green tint to the rock, and a small proportion of hornblende also. Magnetite, apatite and zircon are accessories. The rock may be termed a granodiorite.

A thin section was cut of one of the foreign included blocks. This consists essentially of small angular interlocking quartz-grains set in a felspathic matrix. Flakes of chloritized biotite and cubes of pyrite occur sparingly. The inclusion is an indurated sandstone or quartzite. The junction between the inclusion and the normal granodiorite is marked by a band of quartz which has recrystallized and forms a polysynthetic mosaic.

Uses.—The sole use of this granite in Melbourne has been for the base-course of the Commonwealth Bank in Collins Street.

The stone is polished here, but the polish is not good. Most of the blocks are marred by black spots or inclusions of foreign rocks.

This rock is found at such a great distance from Melbourne, and is so variable in appearance, that it will probably never be widely used. The heart of the stone would almost certainly be more uniform in appearance. The colour is distinctly attractive, and in comparison with other granites this one is more easily worked.

Trawool Granite.

Granite from this locality was quarried for building about 30 years ago. The Monthly Progress Report of the Geological Survey for 1899 (8) records the value of the granite obtained here in 1897 to be £2,100. The quarry site is 60 miles north of Melbourne, and within two miles south-west of the railway siding at Granite, on the Mansfield line. Quarrying was commenced on an outcrop beside the Trawool Creek, the water from which has now filled the quarry hole to within three or four feet of the top of its walls. The vertical walls of the quarry striking approximately north and south and east and west show that the joint system in the stone is good, which is further proved by a polished block measuring 4 ft. by 3 ft. 6 in. by 1 ft., lying near the quarry. This block was rejected because large felspar crystals 2 in. long by ½ in. wide have broken out of it, and cracks have developed in the stone.

The quarry was opened to supply stone for the Equitable Building, but early in the work it was abandoned on account of flaws such as those found in the rejected block described above. Machinery for all processes of dressing and polishing the stone was brought to the quarry. Gabo Island stone was also taken there to be dressed and polished.

Appearance.—It is a grey granite, containing white well-shaped felspar crystals in a finer-grained groundmass. The average grain-size of the felspar measured in a hand specimen is slightly over one-tenth of an inch, so that this granite is a fine-grained one. However, scattered through the rock are occasional large felspar crystals, over an inch in length, making the rock almost a porphyritic granite. These prominent felspar crystals make the stone more suitable for small pieces of ornamental work than for the construction of walls. The colour of the groundmass is darker than Harcourt stone, and consequently it does not change colour markedly after some years' exposure in city air.

Working Qualities.—On a polished surface of this stone numerous pittings occur which are due to the softness of the abundant biotite, which is torn out when the surface is being ground smooth. The stone therefore cannot be said to take a good polish. The tendency of large plagioclase phenocrysts to drop out during the working of the stone has already been noted.

Resistance to Crushing.—This has not been determined.

Absorption Percentage.—After immersion for twelve days a rectangular block of Trawool granite absorbed 0·28% of its weight of water.

Chemical Analysis and Specific Gravity.—The chemical analysis of the Trawool granite has been published (16), and the specific gravity determined as 2·666.

Weight per Cubic Foot.—The weight per cubic foot of this rock is 167 lbs.

Microscopic Examination. — Plagioclase near labradorite, quartz. perthite and biotite are found in the rock. Some of the biotite is chloritized and apatite and zircon are abundant accessory minerals. The rock is named adamellite by Dr. Summers (16). "Xenoliths" such as inclusions of micaceous hornfels and cordierite hornfels found in the Trawool stone show that the quarry is in an area close to the contact between sedimentary rock and adamellite (Tattam, 22).

Uses.—Polished blocks of this stone have been used in the base-courses of Sargood's and Griffiths' warehouses in Flinders Street, Melbourne, in pillars at 459 Little Collins Street, and in ornamental bands, and the steps of the Australian Mutual Provident Building, Collins Street.

Dromana Granite.

Granite outcrops in the hills behind Dromana township, 40 miles south of Melbourne, where a quarry has been made, which is distant about two and a half miles east of the Dromana jetty. The outcrop at this point is very extensive. Joints in the quarry, approximately east and west and north and south, are evenly spaced and are sufficiently far apart for the extraction of blocks 7 ft. long by 3 ft. square. In 1920 a private road was being made to the quarry, and in 1924 a report appeared in the press that a tramway was being constructed which would junction with the Melbourne road, not far from Red Hill station.

Appearance.—This is a green granite whose colour is derived from abundant felspar crystals altered to a bright apple-green. These felspars are rectangular, and stand out almost as phenocrysts from a finer-grained groundmass in which the felspar is creamy-yellow, Zoning in some of the green felspars can be detected by the unaided eye.

The average size of all the felspars is slightly less than one-twentieth of an inch, so that the Dromana stone ranks as a fine-grained building stone. Veins half an inch wide of honey-coloured quartz crystals cross some polished blocks of the stone. No basic segregations mar any specimens which have been examined, nor were they seen in the stone at the quarry on a visit in 1920.

Working Qualities.—The working qualities have been tested in Train's yard, South Melbourne, where large-sized slabs have been

worked up. The granite is reported as comparing favourably with Harcourt granite for ease of working. It spalls off well, and works to a fine edge and polishes well and easily. It repays the work put into it better than does the Harcourt stone, since no unsightly dark patches appear upon the polished surface. The green tint is seen to better advantage on the polished stone.

Resistance to Crushing.—Two tests have been carried out on specimens of this stone obtained in 1918, when quarrying commenced first. Dry cubes measuring approximately two cubic inches were tested. The cubes crushed under loads of 17,870 and 16,300 lbs. per sq. in. respectively (1149 and 1048 tons per sq. ft.). The stone broke with the columnar fracture usual among granitic rocks. The values are high, and since the two tests gave results of approximately the same magnitude, it is safe to forecast for the stone obtained from Dromana strength sufficient for any purpose whatsoever.

Absorption Percentage.—The absorption percentage was determined on a small smooth rectangular block of the granite. After three days' immersion the block was found to have increased in weight by only 0·18%. Hence, like the Harcourt stone, it is nearly impervious to water.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this stone is 2·605; therefore, the weight per cubic foot is 163 lbs.

Microscopic Examination.—This examination shows a holocrystalline, even-grained rock which has undergone a good deal of alteration. The minerals present include felspar, quartz, hornblende, biotite and in very small quantity apatite, zircon, magnetite, pyrites and copper pyrites. Specks of gold are sometimes noticed on polished surfaces. The alteration of some of these minerals has given rise to others. Chlorite has resulted from changes in biotite and hornblende; kaolin and sericite from felspar, limonite from the iron-containing minerals. Orthoclase showing perthitic intergrowth with another alkali type, and a plagioclase, near labradorite, are both present. Minute flakes of chlorite occur throughout the felspar, which are no doubt responsible for its green colour. The proportion of orthoclase to plagioclase felspar being less than 1: 2, this rock is classified as a granodiorite.

Uses.—This stone has been used in the steps of the entrance to and the facings for the block of shops in the Argus building, Elizabeth Street, and a Soldiers' Memorial in Daylesford contains a polished block of it.

It can be obtained in great quantity, the quarry is reasonably near Melbourne, the stone works up well, and has a handsome appearance from its bright green colour, which should give it special architectural value.

It is a stone that could be used on bigger pieces of work than has been the case in the past.

Colquhoun Granite.

Near the railway siding of Colquhoun, 28 miles east of Bairnsdale in Gippsland, and 195 miles east of Melbourne, a red granite has been quarried and worked up in Melbourne for monumental work. The quarry is one mile west of the Colquhoun railway siding and 200 yards south of the railway line. The country in this district is thickly timbered, and the side of a small gully has been chosen for the site of the quarry. There is no overburden on the patch of granite where quarrying was commenced, and though the rock mass appears lens-shaped and dips away from the surface to the north, the covering for some distance is thin, and is composed of unconsolidated sands whose removal should not represent a costly item in the quarrying operations.

A description of this quarry has been published by A. H. Sharpe (20).

The stone has been quarried over an area approximately 40 ft. long by 20 ft. wide and to a depth of 15 ft. Jointing is good in this stone. There are two systems of vertical joints which persist throughout the quarry. The "rift" trends north-north-east and the "grain" makes an angle of approximately 100° with the "rift." The joints are sufficiently far apart for the extraction of blocks of 4ft. 6 in. long by 2 ft. square. The granite exposed at the surface is somewhat iron-stained, but on a quarried surface is free from quartz veins and basic segregations.

Appearance.—This granite has a warm pink colour, and when polished is almost a brick-red. Its grain-size is fine, since its felspar crystals average slightly less than one-tenth of an inch in diameter. It contains beside felspar and quartz only a small amount of biotite mica. Blocks lying at the quarry have a margin of 6-9 inches wide of greyish-green granite, surrounding the normal red rock. Outside this rim again, is a brown, iron-stained band a quarter of an inch thick. A faint brown stain discolours the surface of some polished red blocks. It is only visible when the stone is polished. This rust mark is attributed to the passage of iron-bearing solutions carried upwards through the rock by evaporation. As described under the paragraph "Microscopic Examination," the origin of the rim of grey-green granite surrounding the red stone is ascribed to the same cause. All the stone worked up to the present has been taken from the surface or but slightly below it, and within a zone likely to be affected by evaporation. Neither the stain nor the greyish-green rim occurring along joints is likely to be found in blocks taken from greater depths.

Working Qualities.—This granite is reported to be difficult to work, but the stone takes and keeps a good arris. It takes an excellent and uniform polish, since it is composed almost entirely of quartz and felspar, which are of nearly equal hardness.

Resistance to Crushing.—The crushing strength of this

granite, which was determined by a test on a two-inch cube, is 14,750 lbs. per sq. in. (946 tons per sq. ft).

Absorption Percentage.—This granite absorbed 0·32% of its weight of water after immersion for eight days.

Specific Gravity and Weight per Cubic Foot.—The specific gravity is 2·616 and the weight of a cubic foot of this granite is 163 lbs.

Microscopic Examination.—In thin section the following minerals are found, angular grains of quartz, orthoclase felspar showing perthitic intergrowth with an alkali plagioclase, subordinate plagioclase of composition between oligoclase and andesine, and grass-green and greenish-yellow biotite which occurs very sparingly. Much of the felspar is clouded by alteration to kaolin and epidote. The former is coloured brown by a thin film of iron oxide. The large proportion of orthoclase to plagioclase present in this rock places it among the true granites.

An examination of a thin section of the greenish-grey granite found as a rim 6-9 inches thick around the margin of some of the exposed blocks of the normal red stone shows perthitic felspar, plagioclase of composition near oligoclase, quartz, and a few flakes of chloritized biotite, some of which are green, while one or two whose ferrous iron has been oxidized show a brown staining. In the amount of iron-staining in the perthitic felspar lies the difference between this grey rock and the red granite which it surrounds. In the former, iron-staining is not so marked, and it is suggested that iron has been leached out from the originally stained felspar of the now grey rock, and carried to the surface of the block, or to a joint plane channel. A narrow, very much iron-stained rim, a quarter of an inch wide, was noted around the extreme edge of the block, while the grey rock, which may be regarded as a bleached type, lies immediately inside the narrow rim to a depth of about 9 inches, and inside it again is found the normal red rock unaffected by iron-bearing solutions rising to the surface by evaporation. The original red staining of the felspar is regarded as the work of magmatic vapours. Plagioclase has undergone alteration to epidote in both types and in both is subordinate to orthoclase in amount.

Uses.—A few monumental headstones have been worked up out of the red Colquhoun stone, but otherwise it has not been used. The rock has an attractive colour, a uniform texture, takes a good polish, and is easily accessible to a railway line. The difficulty of working it up and the distance of the quarry from Melbourne, while adding to the expense, should not prevent its use in the future.

Tynong Granite.

The Victorian Shrine of Remembrance is to be constructed of granite obtained from Tynong, Gippsland. Tynong is 43 miles south-east of Melbourne, to which it is connected by rail. Several

large domes of granite form the crest of a small hill one mile north of the railway station, and the quarry is situated on the north side of one of these. There is a downward grade from quarry to railway station, which facilitates transport. This dome of granite rises about 25 feet above the ground, and outcrops over an area of about 30 feet in diameter, with no overburden whatever, and with but a quarter-inch rim of weathered iron-stained material covering the fresh granite. As is usual with granite exposed to the sun's heat, thin sheets tend to exfoliate from this outcrop and split off parallel to the domed outcropping surface. The uppermost one is about 6 inches thick. Very little quarrying has yet been done, but work is proceeding to expose the stone over a larger area in order to obtain material for the Shrine. In the weathered dome two major joints trending north-west and south-east are evident about 12-15 feet apart. These are south of the present small quarry, work in which aims at reaching them. In the preliminary workings now going on the stone is reported to split best along the "board," that is to say, horizontally. When splitting the stone vertically, north and south and east and west directions are at present selected. Lines of holes are drilled in these directions by means of a jack hammer driven by compressed air. Plugs and feathers are then inserted in the holes, and on hammering them a clean break occurs. The object of this preliminary work is to cut back to the major joint or "dry" referred to above, and down to a "board" or horizontal joint. The size of blocks to be obtained is said to be limited only by the capacity of the crane, which can lift 10 tons. The blocks so far removed average 2 ft. 6 in. square by 3 to 5 ft. in length. In the faces of stone exposed by workings in the quarry, perhaps 250 square feet, only two small "black spots" each about 1 inch in diameter were observed. One light-coloured vein about 1 inch in width, composed of coarse felspar crystals, was seen passing through the stone to the surface. Around this vein occurs a good deal of a pyritic mineral. This mineral is fortunately only observed in any amount coating joint planes, and does not extend into the body of the stone, and in a thin section very little pyritic mineral was found, so that if careful selection of pyrites-free blocks is made, little trouble from discoloration by oxidation should be experienced.

Appearance.—The rock is a very light grey granite composed of large white felspar crystals, glassy quartz and a little black mica. A small quantity of an iron sulphide mineral can be seen. The axed surface of the stone is nearly white. As described in the previous paragraph "black spots" are of very infrequent occurrence. Indeed, dark minerals are only rarely found in the main body of the rock, though patches about 12 inches in diameter occur where dark minerals are more plentiful, but are not so concentrated as to constitute a "black spot."

Working Qualities.—This granite is reported to correspond to that from Harcourt in its working qualities. The hardness of the

two is nearly equal. The Tynong stone will work up to a smooth axed surface, and into rounded capitals and pediments, and will take a sharp "arris." It polishes well and easily, and looks distinctly grey when polished. The small infrequent biotite flakes being so much softer than the quartz and felspar grind away more quickly than these, leaving small pits in the polished surface.

Resistance to Crushing.—A rectangular block of this granite of approximately two cubic inches volume in a compression test crushed under a load of 25,700 lbs. per sq. in. (1652 tons per sq. ft.).

This high value is comparable only with the crushing strengths of the granites from Cape Woolamai and Orbost and the dacite from Aura of the stones described here.

Absorption Percentage.—A block of this granite with smoothly ground surfaces absorbed 0·28% of its weight of water after eleven days' immersion.

Specific Gravity and Weight per Cubic Foot.—The specific gravity was determined as 2·633, and the weight per cubic foot calculated to be 165 lbs.

Microscopic Examination.—In thin section the following minerals are seen—allotriomorphic quartz in large and small grains, of which some are interstitial, while some small grains are contained within felspar crystals and collections of other small grains are suggestive of chalcedonic quartz. The greater proportion of felspar consists of large phenocrysts of albite perthitically intergrown with orthoclase, and the remainder is plagioclase of composition between $Ab_{60}An_{40}$ and $Ab_{40}An_{60}$, which occurs in zoned phenocrysts as well as in smaller interstitial crystals. The alkali felspar is somewhat kaolinized, while the core of some of the plagioclases has altered to a sericitic aggregate. In addition to these constituents there is only a small proportion of dark-coloured minerals of which the principal ferromagnesian is brown biotite, in places altered to a green chloritic product. Zircon, apatite, fluorite, pyrite and pyrrhotite are accessory minerals. The two lätter occur very sparingly, and their oxidation should do no harm to the colour of the rock when present in such small proportions. Undoubtedly these minerals occur more freely along joint planes in some parts of the quarry which should be avoided in the selection of blocks for building. The texture is holocrystalline and hypidiomorphic. The rock is a granite.

Uses.—Granite was quarried in this locality some years ago and used as pitchers in the yards at Spencer Street Station. However, as it was found to be slippery for such a purpose (a quality inherent in all granites, and not confined to this particular stone), the granite pitchers were removed. Blocks of granite from this quarry have been used as pedestals for statues in the Queen Victoria Gardens. For facing the exterior of the Shrine of Remembrance this stone is being used in smoothly dressed

axed blocks. The stone with this treatment appears almost dead white, which colour is desired for the Shrine.

The Tynong granite outcrops within 45 miles of the city, is near a main railway line, and there is in sight a very large quantity of stone, so that it should prove a useful stone for building purposes in Melbourne.

Dacite.

Aura, Dandenong Ranges.

A great part of the Dandenong Ranges consists of the rock dacite, which in places has been quarried for building stone and road metal. One such quarry, a quarter of a mile east of the Aura railway station, and about 30 miles east of Melbourne, which has supplied stone for building, was visited. The place chosen for quarrying was at the outcrop of a hemi-cylindrical block about 30 feet in length. The quarry is within five yards of the narrow gauge railway line, on the high or northern side, so that drainage from the quarry should be excellent. The outcrop has a semi-circular upper surface, showing traces of exfoliation, which is stained slightly by rust and lichens. The exposed block disappears into the hill-side under an overburden of about two feet of soil containing boulders.

Two vertical joints, one due north and south and the other due east and west, are excellently developed, allowing the removal of well-shaped blocks at least 2 ft. long by 2 ft. 6 in. wide, since blocks of this area have been cut into slabs 3 inches thick and used for a veneer on a concrete building. A block now lying at the quarry measures 5 feet by 2 feet by 2 feet. No horizontal joint plane is apparent. Very little material has been removed from the quarry up to the present. The cavity worked is 4 ft. high by 10 ft. long by 2 ft. 6 in. wide.

The colour of the exposed stone is uniformly dark, only one acid vein a quarter of an inch wide being observed traversing the outcrop. The stone has been quarried by drilling holes 6 to 8 inches deep, and inserting plugs and feathers in these. No machinery has been installed, and the quarrying done up to the present has been only in the nature of scratching at the surface.

Appearance.—This rock is fine-grained, and the fractured surface is coloured dark-grey to black. Though petrologically a dacite, it falls into the trade class of "black granite." A very slight tendency to parallel arrangement of the mica is apparent in freshly-broken pieces in the field. The rock when polished is darker in colour, since there are only a few sparkling crystals of felspar to break its uniform blackness. A smoothly ground, unpolished surface of the stone has a blue tint. Quartz veins a quarter of an inch wide occur so rarely that only one out of every five finished blocks of stone contains one. The colour is unpopular in the building trade, where it is condemned as "cold." For

special purposes, such as monumental work, however, the distinctive almost black colour of the polished face should be an asset.

Working Qualities.—The cutting of a small cube for a test did not present greater difficulty than is to be expected with any quartz-bearing igneous rock, though the stone is said by one man who has had experience with it, to be difficult to work. This man spoke also of the existence of "drys," whose occurrence on a dressed block makes it necessary to reject the block. A sharp knife-like "arris" was obtained on the test block. The rock takes a high polish, and its surface remains smooth and without pits after grinding. However, as the individual minerals are small and dark-coloured, there is no relief on a polished surface except for some milky quartz and a few grains of a metallic mineral. On this account probably, the polished Aura stone when used for building is relieved by blocks of unpolished stone finished by patent hammering, which gives it a light grey colour.

Resistance to Crushing.—A rectangular block approximately 2 sq. in. by 1·6 in. high crushed under a load of 26,400 lbs. per sq. in. (1672 tons per sq. ft.).

Absorption Percentage.—After immersion in distilled water for 12 days a rectangular block of this stone absorbed 0·16% of its weight of water.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this stone is 2·765, and the weight per cubic foot is 172·5 lbs.

Microscopic Examination.—This rock is remarkably free from alteration products. Felspar of composition between labradorite and andesine in zoned hypidiomorphic crystals is the most abundant mineral. A few allotriomorphic crystals of quartz occur. Of ferromagnesian minerals biotite is more prominent than pyroxene, which is represented by hypersthene. A few irregular crystals of iron sulphide are present. In a dark-coloured rock such as this one, discoloration due to the oxidation of an iron sulphide mineral need not be feared. The groundmass is granular and micro-crystalline in texture, and consists of small circular, equidimensional felspar grains and some quartz. The felspar crystals are very small, and the determination of their species is difficult, but many of them being clear and untwinned suggest orthoclase. Accessory minerals are magnetite, apatite and zircon. The rock is a biotite hypersthene dacite.

Uses.—This stone was used in a branch of the English, Scottish and Australian Bank, at the corner of Swanston and Little Bourke Streets, Melbourne. This was demolished in 1927, and upon rebuilding the dacite was not used. Polished slabs of the stone were used mainly, but around the doorway relief was given to the dark Aura stone by specimens of a grey rock with an axed finish. The locality of this rock is uncertain.

The abundant supply, the proximity to a railway track, and the uniformity of colour are all points in favour of the use of this

stone, though it should be noted that Aura is on a narrow gauge railway line, and any quarried material has therefore to be transferred at Upper Fern Tree Gully to wide gauge trucks.

Porphyry.

Tallangatta.

This district contains many igneous rocks, one of which, a porphyry, has been used in Melbourne as an ornamental stone. Details of the position of the quarry with respect to the town of Tallangatta, which is 212 miles from Melbourne in a north-east direction, or of the nature of the outcrop of the rock, are not known to the writer.

Appearance.—The stone used is light pink in colour, and has large porphyritic crystals of a cream-coloured rhombic-shaped felspar and corroded crystals of quartz set in a fine-grained pink groundmass. Its attractive colour shows well when the stone is polished. Other types from the same district have been examined, which should also serve well as ornamental stones. One of these has the greenish-brown colour and fine-grained appearance familiar in the "trachyte" of Bowral, New South Wales. On a polished surface numerous rectangular porphyritic crystals of green felspar are seen. This stone polishes excellently.

Working Qualities.—A specimen of the pink rock was ground smooth and polished in the laboratory. A very even surface was obtained, and a high polish appeared on it. Other working qualities are unknown to the writer.

Resistance to Crushing.—This has not been determined.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this porphyry is 2·565, and its weight per cubic foot is 160·5 lbs.

Microscopic Examination.—Examined in thin section the rock is found to be much altered. Large quartz crystals, some idiomorphic and some corroded by the surrounding groundmass, stand out from among the rest of the minerals, which are clouded with decomposition products. Small porphyritic crystals of felspar occur, but all traces of twinning and cleavage are masked by a thick film of secondary products, such as kaolin, sericite and iron oxide, so that the species cannot be determined. Fibrous aggregates of a ferromagnesian mineral, which is a chloritic product of the original biotite, are seen. The groundmass of the rock is crystalline, and consists mainly of small felspars. The rock is a quartz felspar porphyry.

Uses.—A large rectangular block of the pink stone has been used in the Eight Hours Day Monument, erected in 1888 near Parliament House, and moved in 1923 to its present site, at the corner of Victoria and Lygon Streets. The steps and pillar of the monument are constructed of Harcourt stone, while the central block at the base of the pillar bearing the inscription comes from Tallangatta.

Its warm pink colour, the large well-shaped, cream-coloured felspar crystals, and its good polish make this stone a very handsome one.

Basalts.

Malmsbury Basalt.

The basalt of Malmsbury and district was quarried for building stone and road metal before 1861, as notes on Quarter Sheet 9 NW. published in that year record quarries for this stone. Many of the early quarries were in the neighbourhood of Green Hill, a point of eruption three and a half miles north-east of Malmsbury. Basalt quarries are working now about two miles east of Malmsbury, and half a mile west of the railway siding of Edgecumbe, on the Redesdale branch line. Several small quarries are in operation on a low rise about twenty feet in height, which at one time formed the outer bank of a meander of the Campaspe River. The river now flows to the east of its old course, and this deserted meander is now a marsh. The quarries are working into the old river bank, which by this means has been cut back about 30 feet. Pillars of stone which are useless on account of the amount of honeycomb basalt in them are left standing in the quarries. The vertical jointing system in this stone is not particularly marked in any given direction. Those working on the stone say it may be split vertically with equal ease in any direction, and vertical joints intersecting at various angles were observed in the quarry. Some of these joints are filled with a weathered layer of clay or "reef," up to one foot in thickness, between the solid basalt. These are called "clay" or "open" joints, and those where no clay appears are known as "tight joints." The stone with "tight joints" is more difficult to quarry. The vertical joint planes meet at angles which suggest that columnar jointing, with each column of a large diameter, is prevalent in this flow as in other flows of basalt. The horizontal joints or "bed" are rather uneven, and follow more or less the upper surfaces of layers of honeycomb basalt which are found through the solid stone. A characteristic section in the quarry is seen in a face of basalt about 16 feet in height. A layer of soil 1 foot in depth covers 4 feet of solid basalt, which overlies 14 inches of honeycomb basalt. Below this, 15 inches of solid stone overlies a thin "reed" or sheet of porous stone half an inch in thickness. Below this depths of solid stone of about 18 inches width are separated by layers of honeycomb basalt perhaps 6 inches in thickness or by narrower "reeds." The thicknesses of the layers of solid stone are not uniform throughout the quarry. The "honeycomb" basalt—i.e., the extremely porous stone—since it is developed in bands 6 to 14 inches thick, may mark the quickly cooled upper surfaces of individual flows, to which a great deal of gas finds its way from the body of each flow, and so forms the "honeycomb" basalt at the surface of the flow. Later, this honeycomb layer is covered

by a new flow of basalt. The ease with which horizontal jointing takes place immediately above a layer of "honeycomb" basalt is probably due to this junction between flows. The "reeds," which are thin sheets of porous basalt, are never more than half an inch thick. These often occur in a horizontal plane, but also an "up and down reed" occasionally passes through solid stone from one honeycomb layer to another. It is thought that the "reeds" represent the tracks of bubbles of gas which are carried horizontally for a certain distance and then may find their way to the surface by travelling vertically or diagonally up through the flow, making an "up and down reed." Their origin is thus pictured as similar to that of the "corks" found commonly in Footscray basalt and described later. In the "reed," however, there has been no subsequent filling of the steam cavities. A type of "reed" difficult to account for is one which follows a horizontal plane for some distance, bends at right angles to a vertical plane for about 6 inches, then back to a horizontal plane again for a foot, following this the "reed" bends down again along a vertical plane, and finishes up after another bend in the same horizontal plane in which it commenced. The bubbles appear to be surmounting an obstruction of stone already solidified, perhaps a block of foreign stone being carried along by the molten basalt.

FIG. 1.—Path of "reed" in basalt, Malmsbury.

In the stone in this part of Malmsbury no "corks" are seen, but half a mile away basalt outcropping on the main road contains them. They are described and their origin is discussed in the description of the Footscray basalt. As in many other igneous rocks, "drys" occur in this basalt. They are sometimes marked by a brown iron-stained thread in the good stone as though some oxidation of iron had taken place along them.

Appearance.—The stone is fine-grained, porous and slate-grey in colour. It contains many colourless, needle-like zeolite crystals. Its uniform appearance is monotonous and unrelieved by any sparkling mineral. Two grades of stone are recognised, depending upon the porosity. First quality stone is porous, but none of the pores is larger than one-fortieth of an inch in diameter. Second quality stone is porous and contains these minute pores, but in addition some larger ones, whose diameters vary between one-eighth and one-half inch, are scattered irregularly through it.

Working Qualities.—The Malmsbury basalt is quoted by quarrymen as the standard of excellence among building stones when working qualities are considered. By means of a scavelling pick a block of stone obtained from the quarry is readily dressed

to a regular shape. "Drys" in the stone, as described above, are the only flaws against which the workman has to guard when selecting blocks for dressing. The average size of the finished blocks obtained is 4 ft. long by 2 ft. by 1 ft. In a report by Lidgey published in 1894 (6), the Malmsbury basalt is described as taking "a fine polish," with which statement the writer cannot agree. A piece of first quality Malmsbury was smoothed and polished, but as was expected, the pores in the stone are so numerous that the smallest polished surface is broken by gaps where the pores intervene, and in many of them the rouge powder used for polishing lodges and is extremely difficult to remove. To overcome this disadvantage canada balsam was poured on the smooth surface of a heated block of the basalt, then baked, and allowed to cool. Grinding removed the superficial layer of balsam, and the surface was then polished. An even polish, though a poor one, resulted, since there were few pores unfilled by balsam.

Resistance to Crushing.—A two-inch cube of the stone was crushed under a load of 8,620 lbs. per sq. in. (554 tons per sq. ft.).

Absorption Percentage.—The stone absorbed 2·16% of its weight after immersion in water for five days. Absorption was complete after this period, since three weeks later no material increase in weight was found in the test block.

Specific Gravity and Weight per Cubic Foot.—The specific gravity is 2·595, and the weight per cubic foot 162 lbs.

Microscopic Examination.—The rock contains plagioclase felspar laths whose mean composition is that of labradorite, abundant squat prisms of faint green augite, corroded crystals of olivine, the larger ones completely changed to brown iddingsite, and the smaller ones colourless with a border alteration only. Magnetite is common, many crystals of it occurring in long narrow flakes. The texture is ophitic, since some of the felspar is enclosed by later crystallizing augite. On account of the extreme porosity of the rock, a thin section is rather broken. The rock is an olivine basalt.

Uses.—Malmsbury basalt was at one time used very extensively for the basecourses of large Melbourne buildings. The stone from the Green Hills quarries probably figures in many of these. Nowadays some of the stone from the quarry visited near Edgecumbe is used for basecourses, but it is generally sawn into steps and cemetery kerbing. Malmsbury basalt forms the basecourses of the following buildings in Melbourne:—English, Scottish and Australian Bank (head office), Bank of Australasia, Australian Mutual Provident, Royal Insurance, London and Lancashire Insurance, Northern Assurance, Alliance Insurance and Guardian Insurance Buildings, and many others. It is used in the gateway in the main entrance to the University. In combination with Footscray basalt it is used in the Melbourne Grammar School. Malms-

bury basalt is not accepted for use on the roads, as on account of the ease with which it is worked it is regarded as too soft for this purpose. The ease with which it may be worked recommends this stone for use for building, when its dull appearance will serve as an effective contrast to a lighter-coloured stone, but it is too unattractive to be used alone in construction.

Footscray Basalt.

The quarry visited at Footscray lies north of the Footscray railway station, and is four miles west of Melbourne. Quarrying commenced here more than 25 years ago, and in that time stone has been removed over an area 150 yards square for an average depth of 20 feet. The ground here was practically horizontal originally, and the result of quarrying has been to leave a hole in the ground with the dimensions given above. Several basalt flows have occurred in this area, the later ones being superimposed on the earlier, and marked junctions occur between them. Drainage from the quarry is reported as good, since all rain water flows away through a vesicular, iron-stained basalt which forms the bottom of the main quarry. The depth below the surface at which the iron-stained band lies, varies in different parts of the quarry. At the northern end this band is 21 feet below ground level. Immediately above it lies 15 feet of solid rock, from which building stone is obtained. In the eastern part of the quarry this same vesicular band is seen 10 feet below the surface of the ground, and stone is quarried from beneath it, presumably in an earlier flow. The top of the quarry is formed by 5 feet of stone showing irregular columnar jointing. The jointing system is very irregular, even in the solid stone. In quarrying, a vertical drill-hole perhaps 26 feet deep is made with a pneumatic drill, until the iron-stained honeycomb layer is reached. A charge of powder in this hole blows out the side of the quarry, and may dislodge blocks large enough for building stone purposes. Such a block with very irregular surfaces and measuring 8 feet long by 3 feet square was seen by the writer. It was to be cut up by the use of plugs and feathers into regular-shaped kerb stones 6 or 7 feet long by 12 inches by 7 inches. Stones which spall well are cut into larger blocks suitable for basecourses. Otherwise the building stone market is not now catered for.

Horizontal layers of vesicles traverse the solid rock. They average half an inch in width, but occasionally reach two inches. They are known as "reeds," and represent the paths of bubbles of gas which have travelled through the lava along the direction of the "reed." The gas has taken a horizontal track along the level where the viscosity of the crystallising lava has prevented its further passage upward. The lava being still in motion, has drawn out the bubbles of gas into ellipses, whose long axes are arranged parallel to the direction of movement. In some "reeds" the vesicles are lined with white carbonate crystals, which pene-

trate into a central cavity. In such a case the quarrymen speak of a "silver reed." Elsewhere the solid stone is pierced by vertical cylindrical pipes known as "corks." These are channels whose diameters vary from one to three inches, which pass from the bottom honeycomb layer of the quarry vertically up through the stone until within 14 feet of the surface. In the uppermost 14 feet of the quarry is stone showing a great development of platy and horizontal jointing, which may represent a different flow of basalt, and through which the "corks" do not pass. The channels or "corks" show up in the normal basalt, since their margins are defined by rows of vesicles, and they are more porous than the normal stone, carrying as they do an average of 20 pores to the square inch. The pores are the shape of irregular triangles, or quadrangles, or they are circular. Some are filled with a white

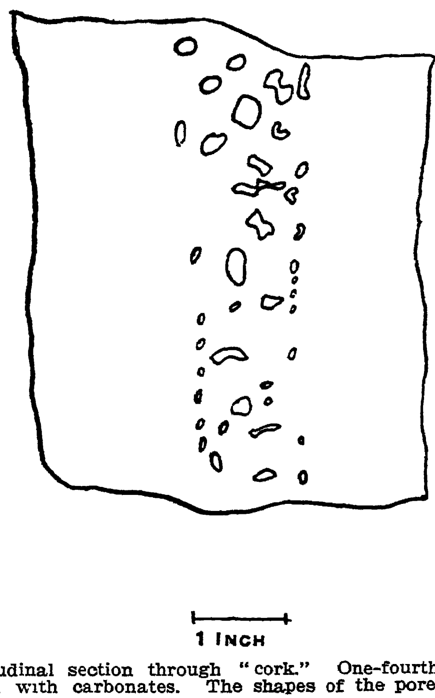

FIG. 2.—Longitudinal section through "cork." One-fourth of the larger pores are filled with carbonates. The shapes of the pores are characteristic.

carbonate mineral. The rock forming the matrix of the "cork" is finer-grained than is the normal rock. Near the bottom of the flow the "corks" are narrow, being about one inch in diameter, while towards the top they expand to about three or four inches across. At the bottom of the "cork" the white carbonate coating to the pores, which makes a "silver cork," is more commonly found than at the top of the "cork," where the vesicles remain

empty, forming a "black cork." The "corks" are practically vertical, but owing to the irregularity with which a stone splits after a charge of gelignite, they appear in circular, elliptical or half-moon-shaped cross-section and look like sporadic occurrences. One "cork" was traced vertically by the writer for twelve feet

FIG. 3.—Characteristic cross-sections through "corks."

through the stone, while experienced quarrymen state that they have traced a single "cork" through the 40 feet of the stone which is worked. "Corks" are the channels by which the gases imprisoned in a lava escape to the surface. On account of the passage of gases through such a channel, the lava in its neighbourhood is rendered very porous, and is retained in the liquid state for a longer period than the surrounding lava, one result of which is the larger percentage of isotropic material seen in a thin section of a "cork," as described later under "Microscopic Examination." The "cork" expands when nearing the surface, since the overlying pressure is less.

Du Toit describes (11) in the diabasic lavas of Barkly West, South Africa, "pipe amygdales" or "bubble trains," structures very similar to "corks," which he ascribes to the "escape of steam generated in the flowing of molten rock over moist surfaces." In Victoria, since many of the basalt flows have filled old stream valleys, an analogous origin is not impossible. As described earlier, the floor of this quarry is formed by an iron-stained layer of stone which may represent the lower surface of the flow in contact with the bed of the old river.

Appearance.—This basalt is a fine-grained rock coloured dark-grey, with a slight bluish tint, which earns it the trade name of "bluestone." The whole rock is pierced by fine pores, and in addition larger circular vesicles averaging one-tenth of an inch in diameter occur about one inch apart throughout the stone. The rock is denser than the basalt from Kyneton, in which the pores and vesicles are more numerous. It contains small sparkling felspar crystals and occasionally a yellowish-green powdery mineral, probably halloysite. Blocks of otherwise solid stone contain elliptical or circular patches of varying size, which are cross-sections through the "corks" described above. In paving stones the "corks" stand up above the surface of the rocks after a certain amount of traffic over the pavements. This is seen especially on the north side of Bourke Street, between Swanston and Russell Streets. This greater resistance to wear is considered to be due to the coarser texture of the "cork," as compared with

the finer-grained nature of the matrix. Another type of abnormality found in this rock is the "flint," which is a patch rich in calcium carbonate, where all pore spaces are filled with this white mineral, which has crystallized from solutions perhaps imprisoned in the rock when crystallization of the main flow prevented their escape. The "flints" are so known because it is reported that the rock in which they occur is more difficult to work than the normal basalt. They are also found in the Kyneton stone.

Working Qualities.—In spite of the irregular jointing this stone spalls remarkably well. An experienced worker easily breaks it into rectangular blocks with a hammer. However, it is not so easy to work as the more vesicular Malmsbury and Kyneton basalts. A sample was ground smooth and polished with rouge powder, which filled all the small pore spaces in the basalt, and no amount of scrubbing would remove it. The solid portions between the pores took a moderately good polish, showing a greyish-brown colour, but the general effect is far from pleasing. This result illustrates the common saying, "Basalt will not polish."

Resistance to Crushing.—A three inch cube of Footscray basalt which was crushed in 1891 fractured under a load of 10,577 lbs. per sq. in. (680 tons per sq. ft.). A two inch cube of this stone was made from material obtained in 1926 from a quarry at Footscray, and this stone proved stronger than that crushed earlier. Its crushing strength was 16,300 lbs. per sq. in. (1048 tons per sq. ft.).

Absorption Percentage.—The absorption percentage of this stone is 1·45. The absorption of water by the basalt is gradual and continuous. In five days' immersion a block measuring about one cubic inch increased in weight by 1·09%, but after thirteen days its weight had increased by 1·44%. At the end of seventeen days, when the stone had absorbed 1·45% of its weight of water, saturation was considered complete.

Chemical Analysis.—A chemical analysis of the basalt from this quarry has been made in the Victorian Mines Department Laboratory by Mr. A. G. Hall, but has not been previously published. By the courtesy of the Geological Survey permission has been given to publish it in this paper with other analyses.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of the stone obtained from this quarry determined by weighing a specimen first in air and then in water is 2·570. From this value the weight per cubic foot is found to be 161 lbs. It will be noticed that the specific gravity given with the chemical analysis is 2·839. This value was obtained by weighing the powdered basalt, and since basalt is a porous rock the disagreement between the two determinations is intelligible. The first method is more useful for building stones, though it is difficult to carry out in the case of a porous rock, where some of the water is absorbed while weighing is proceeding. The result obtained is known as the

"apparent specific gravity," and from it the weight per cubic foot of the stone is calculated.

Microscopic Examination.—A thin section of the normal stone of the quarry contains laths of plagioclase whose composition is between labradorite and bytownite. Many of these are set inside titaniferous augite crystals in the typical ophitic texture. Some augite shows strain polarization. Olivine is abundant, and has a brown alteration product, iddingsite, around its edges and along its cleavage planes. Occurring interstitially between some felspar laths is a colourless substance thickly studded with black globules of iron oxide and some long laths of an iron oxide mineral, magnetite or ilmenite. Since this mineral occurs in hexagonal plates, and in brown skeletal crystals, forms more characteristic of ilmenite than of magnetite, it is more likely to be the titanium-bearing iron oxide, ilmenite. Titanium is also present in the augite of this rock. The colourless matrix in which the ilmenite occurs was at first taken for volcanic glass, but Professor Skeats has pointed out that while some of this material is isotropic, much of it is not, and also the refractive index is too low for a basaltic glass, nor has it the characteristic greenish-brown colour of such a glass, and further glass in basalt is found only in a narrow tachylytic margin of a basalt flow, always less than one inch in width, while the specimen from which this section was cut comes from within a uniform mass of basalt, certainly 30 feet in thickness. In ordinary light the refractive index and colour of this material are similar to the felspar of the basalt. Where it is anisotropic its polarization colours are low in the first order, and occasionally there is a suggestion of zoning in the interstitial material. These considerations point to the interstitial material being felspar. It has been the last material to crystallize from the liquid state, and has thus filled up interstices, a role commonly taken by the quartz of quartz-bearing rocks. The iron oxide carried in this liquid has separated in the form of globules. In some cases this liquid has been supercooled below the temperature of crystallization of felspar, and has eventually solidified in the form of a felspathic glass, and hence is isotropic. In ordinary light this isotropic material is in colour and refractive index indistinguishable from that which is anisotropic, and the former also contains the iron oxide globules found in the latter. Where an augite crystal is set in this matrix the iron oxide has been drained from the latter to go to the formation of augite, and the augite crystal is surrounded by a narrow rim of clear, colourless, felspathic matrix. The rock is a porous olivine basalt.

In a thin section of a "cork" or pipe-amygdale, the materials of the normal rock are found. The interstitial felspathic glass is more abundant here, and in this case practically all of it is isotropic. In this section in addition to the globular form the iron oxide also occurs in hexagonal plates, and in brown feathery skeletal crystals (Plate XVI., Fig. 2) suggestive of incipient

crystallization brought about by the mother liquor being retained in the liquid state longer than where the iron oxide is found in the globular form. When it is remembered that this material comes from the former channel for the passage of gases its less crystalline state is explicable. While passing through the "cork" the gases would tend to keep the neighbouring lava in a state of flux, with crystals of augite, olivine, felspar and iron oxide suspended in a liquor which, drained of other constituents by their crystallization and largely felspathic in composition, became supercooled below its freezing point. After the passage of most of the gases, that is to say of the fluxing agent, sudden solidification or quenching would cause the formation of felspathic glass as the matrix binding together the crystalline material. Many pores are filled with a concentrically or radially arranged calcium carbonate mineral, probably aragonite. In a thin section of a "flint" the minerals of the normal rock may be recognized. Many of the pores in the rock are filled with aragonite. Here too the felspathic matrix occurs in both isotropic and anisotropic forms, the former preponderating. Carried in it is iron oxide in both globular and skeletal-crystal forms. Hematite is noted very occasionally in the section.

Uses.—The stone from this quarry is used for screenings, for foundations in concrete roads, for gutter pitchers, paving slabs, doorsteps and staircases and, when large enough blocks are obtainable, for building stone. It is commonly used in basecourses, and can be seen in the base of the Melbourne Town Hall and of the Telephone Exchange. St. Patrick's Cathedral, Melbourne, has been constructed entirely of Footscray basalt, as have been numerous Melbourne warehouses.

The large supply, the proximity of the outcrop to Melbourne, and the comparative ease of dressing it, are to be reckoned in favour of this stone's use in Melbourne. Its dark colour considerably lessens its suitability as a building stone, and while it should make it more suitable for monumental work, the fact that it will not polish curtails its use for this purpose.

Kyneton Basalt.

Basalt in the neighbourhood of Kyneton, as well as near Malmsbury, has been quarried for building stone for many years. A quarry visited three miles south-east of Kyneton, and two miles north-west of Carlsruhe, is on the site of a very old one on a low ridge running parallel to and about one mile east of the railway line, and is 55 miles north of Melbourne.

An area 30 ft. by 40 ft. has been quarried to a depth of 25 ft. By the lease under which the stone is obtained, the quarry has to be filled as stone is taken out, so that only a small pit is left where present quarrying operations go on.

The quarry face shows a layer of overburden 2 ft. in depth, while for a further 5 ft. below the stone is broken into large

boulders showing spheroidal or "onion" weathering. Below this the stone is solid though at intervals very vesicular bands about 2 in. in width occur. The stone in the upper portion of the quarry contains some sporadic vesicles or "blow-holes," which are larger than the pores of the normal vesicular basalt. The stone in the lower 15 ft. of the quarry is free from them. A series of horizontal and north-south and east-west vertical joints traverse the stone, along which weathering agents have found a track, forming a band of clay one inch in width as a result of the alteration of the basalt. Hence the joints are called "clay joints." From the "clay joints" the flaws called "drys" pass in to the good stone. The stone is liable to split along a "dry" and a block must be rejected if a "dry" appears on a dressed surface. The dry may only show after the dressing of the block is complete. The stone is found to be without "blow-holes" or "drys" about 25 feet below the surface, where flawless regular blocks 10 feet by 8 feet by 7 feet can be extracted. Vertical holes 6 inches deep are drilled 8 inches apart by means of a jumper drill along a vertical "clay joint." After the block has cracked vertically, that is, along the "cut," holes passing horizontally into the stone for 18 inches are drilled 2 feet apart on the front of the stone just above a line of honeycomb basalt if any is present. Plugs and feathers at first and, later, "lifters" are inserted in these holes, and a horizontal crack occurs which is called the "board." Along the east and west vertical joints a good face of stone is obtained. Along other vertical joints the stone is apt to break irregularly.

Appearance.—This basalt is a drab-grey vesicular one, with here and there groups of vesicles filled with an opaque white mineral which effervesces with acid, and when examined in thin section is found to be calcite. The patches which contain calcite are known as "flints," and are said to blunt tools used on the basalt. It is difficult to see why the soft mineral, calcite, in these patches should have earned them the name of "flints," though when it is remembered that elsewhere the vesicles are empty the assertion that the "flints" are harder than the normal stone is probably explained. Some vesicles are penetrated by needle-like crystals of probably a zeolite mineral, natrolite. An axed surface of this basalt is lighter grey in colour than is a rock-faced block, but both colours are monotonous and rather unattractive.

Working Qualities.—This stone is reported to be easier to work than the Footscray basalt, though it is not so easy as that from Malmsbury. In common with these other basalts it is easily broken by the hammer along plane surfaces at right angles, giving nearly smooth rectangular blocks. A great deal of quarry damp is noticed in the stone when a chip is flaked off a block just after it has been quarried.

This basalt is too vesicular to be susceptible of polishing.

Resistance to Crushing.—This porous basalt has a lower crushing strength than the denser Footscray basalt. The Kyneton

stone crushed under a load of 9,220 lbs. per sq. in. (593 tons per sq. ft.).

Absorption Percentage.—Absorption percentages of both normal and "flint" types of the stone were obtained. The normal stone absorbed water slowly, and saturation was not complete until the stone had been immersed for 24 days, when it was found to have absorbed 2·92% of its weight of water. The absorption percentage of the "flint" type was 1·77, which indicates that in a "flint" nearly half the pore space of the normal basalt has been filled with secondary minerals.

Normal Footscray basalt has an absorption of 1·45%, i.e., only half that of normal Kyneton stone. The porosity of the latter makes it the easier stone to work.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of the stone is 2·615, and its weight per cubic foot is 164 lbs.

Microscopic Examination.—A thin section shows fresh, unaltered labradorite felspar and augite, olivine surrounded by a rim of reddish-brown iddingsite, and some magnetite. The structure is vesicular, but many of the vesicles are coated with calcite. The mineral content and texture of this rock are typical of normal basalt.

Uses.—The main use to which the Kyneton stone is put is the construction of basecourses. Its dark colour makes an effective

Tabulated List of Tests.

Name and locality	Specific Gravity	Weight per Cubic Foot in Lbs.	Absorption Percentage	Crushing Strength Lbs. per Sq. In.	Crushing Strength Tons per Sq. Ft.
Granite, Harcourt	2·678	167·5	0·11	11,444	736
				11,333	728
				8,510	547
Granite, Wangaratta—					
Type A	2·512	157	1·45	19,600	1261
„ B	2·324	145	3·75	7,110	457
„ C	2·446	152·5	4·08	9,670	622
Granite, Cape Woolamai	2·643 (16)	165	0·18	27,100	1743
Granite, Gabo Island	2·635 (16)	165	0·39	15,200	979
				14,900	950
				17,500	1128
Granite, Orbost	2·803	175	0·15	25,400*	1633
				15,300	984
Granite, Trawool	2·666 (16)	167	0·28	not determined	
Granite, Dromana	2·605	163	0·18	17,870	1149
				16,300	1048
Granite, Colquhoun	2·616	163	0·32	14,750	946
Granite, Tynong	2·633	165	0·28	25,700	1652
Dacite, Aura	2·765	172·5	0·16	26,000	1672
Basalt, Footscray	2·570	161	1·45	10,577	680
				16,300	1048
Basalt, Kyneton	2·615	164	2·92	9,220	593
Basalt, Malmsbury	2·595	162	2·16	8,620	554

*** Not actually broken, but on the point of breaking.**

contrast with a lighter-coloured superstructure. The basecourses of the New Arts Block at the Melbourne University are constructed of basalt from this quarry in blocks measuring 8 ft. 9 in. by 5 ft. by 1 ft. 6 in. Waste pieces left after the shaping of larger blocks are trimmed up for gutter pitchers, etc.

The large quantity available, the ease of extraction and working, and the possibility of obtaining big blocks, are all points in favour of this stone.

Chemical Analyses.

	1	2	3	4	5
SiO_2	70·94	76·31	72·49	69·19	50·86
Al_2O_3	13·99	13·09	13·48	13·45	13 84
Fe_2O_3	0·35	0·41	1·16	2·71	4 70
FeO	3 02	1·07	2·09	2·78	6·56
MgO	0·80	0·36	0·49	1·06	8·94
CaO	2·35	0·65	1·31	2·04	8·45
Na_2O	3·94	3·00	3·38	2·89	2·59
K_2O	3·66	4·76	4·06	3 94	0 75
H_2O+	0·21	0·29	0·76	0·77	0 82
H_2O-	0·11	0·11	0·18	0·16	0 57
TiO_2	0·58	tr.	0·46	0 51	1·93
P_2O_5	tr.	——	tr.	0·18	0·23
CO_2	——	0·66	tr.	0·07	nil
MnO	——	0·11	0·13	0 14	0·20
Li_2O	——	tr.	tr.	tr.	tr.
Cl	——			tr.	tr.
NiO	——	0·01		nil	0·01
SO_3	——	nil	nil	nil	——
CoO	——	——		nil	tr.
BaO	——	——	——	——	tr.
Cr_2O_3	——	——	——	——	0·05
S	——	——	——	——	0·03
Less $O=S$	——	——	——	——	0·01
Total	99·95	100·43	99·99	99·89	100·52
Specific Gravity		2·643	2·635	2·666	2·839

1. Adamellite, Harcourt Quarry (Analyst, G. Ampt) (16).
2. Granite, Cape Woolamai (Analyst, A. G. Hall) (16).
3. Granite, Gabo Island (Analyst, J. Watson) (16).
4. Adamellite, Trawool Quarry (Analyst, A. G. Hall) (16).
5. Basalt, Eldridge's Quarry, Footscray (Analyst, A. G. Hall).

Summary.

In this paper are described fourteen Victorian igneous rocks used as building stones. It has been found that most of these are excellently adapted for such a purpose so far as their durability is concerned, but the long distance at which some of them occur from a market must add to the expense of using them, as for example the rocks from Gabo Island, Colquhoun, Orbost and Wangaratta.

Some are considered most suitable for ornamental purposes, as they consist of large crystals included in a fine-grained groundmass. Such are the stones from Tallangatta and Trawool. Another set, including the Aura dacite and the three basalts, being very dark and sombre in colour, needs to be combined in a building with a lighter-coloured rock to give relief.

The rock so far obtained from the quarry at Orbost is found to be too uneven in texture to be usable with success. As is pointed out in the report on that stone, probably a more even-textured stone freer from "black spots" and sedimentary inclusions will be found at depth in this quarry.

So far as working qualities are concerned, the basalts stand out as those most easily worked; next in order of ease is probably the Wangaratta stone, followed by that from Orbost. The stone from Harcourt is well known to be, for a granite, not difficult to work, while the Tynong granite is reported to approximate closely to it in ease of working.

So far as attractiveness of appearance, convenience of situation to the capital, and amount of stone available are concerned, the stone from Dromana seems to merit development; while, though its situation is somewhat remote, and the quantity perhaps limited, the working qualities and appearance of the Wangaratta stone should recommend its further use.

In the case of the granites from Wangaratta, Orbost, Dromana, Colquhoun, Tynong, the dacite from Aura, the porphyry from Tallangatta and the basalts from Footscray and Kyneton, the petrological descriptions of these rocks are here published for the first time.

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EXPLANATION OF PLATE XVI.

Fig. 1—Microphotograph—Altered Granite, Warby Ranges, Wangaratta. Ordinary light, × 26.

1. Orthoclase.
2. Hematite.
3. Hematite penetrating along cleavage crack parallel to *c* (basal pinacoid).
4. Hematite penetrating along cleavage crack parallel to *b* (clinopinacoid).

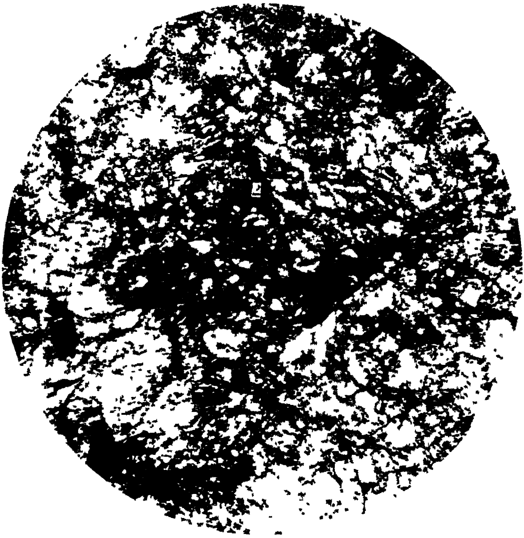

FIG. 1.

FIG. 2.

FIG. 2—Microphotograph—Basalt, Standard Quarries, Footscray, showing texture of " cork " or pipe amygdale. Ordinary light, × 115.

1. Brown skeletal crystal of ilmenite.
2. Hexagonal cross sections of ilmenite.
3. Flakes or flattened crystals of ilmenite.
4. Augite.
5. Plagioclase.
6. Isotropic felspathic matrix clouded by globules of iron oxide.
7. Anisotropic felspathic matrix clouded by globules of iron oxide.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. X.—*Long Range Rainfall Forecasting from Tropical (Darwin) Air Pressures.*

By E. T. QUAYLE, B.A.

[Read 11th October, 1928; issued separately 3rd April, 1929.]

Darwin has come to occupy a position of singular importance in world meteorology, especially with regard to its air pressure records. These have not only proved valuable as aids to forecasting Indian weather, but show striking correlations with the meteorological phenomena of many other areas, chiefly tropical. It therefore seemed reasonable to hope that since our Southern inland rains are mainly of tropical origin, they also would show some relation to Darwin air pressures. This paper gives the results of an attempt to show whether this is such as to be of use for forecast purposes.

That tropical conditions have a large and direct control over our Southern weather I have already shown by Bulletin 15, Commonwealth Bureau of Meteorology. In this case the minimum temperatures, which give some indication of the total blanketing effect upon the earth's surface of the humidities of the air at all levels of the atmosphere, were used. From these it was deduced that even in winter vast bodies of moist tropical upper air not infrequently invade the continent, and that the rain production of storm systems generally is dependent upon their being met by these invasions. It was found, too, that the semi-permanence of tropical conditions made possible during the winter half of the year forecasts of rain probabilities as much as three weeks ahead, and for this Darwin was the station mainly relied upon.

Of the data up to the present available those provided by the surface air pressures are probably the best for tracing changes in the general atmospheric circulation due, say, to the varying output of solar heat, the interplay of ocean currents and storm systems, etc. And any change in the distribution of pressure over the globe must have its influence upon the development and paths of storm systems, and so upon the rainfall of any locality. It is in the tropical belt that such changes might be expected to reveal themselves first.

This investigation consists mainly of comparisons between the monthly means of air pressure at Darwin, and of the rainfall at ten representative stations in Northern Victoria. These are Swan Hill, Echuca, Yarrawonga, Warracknabeal, Charlton, Bendigo, Shepparton, Dookie, Horsham and St. Arnaud.

As with the minimum temperatures, so with the air pressures in tracing rainfall relations, it will be seen that the tropical control of our Southern inland rains is apparently limited to the

winter half of the year. This is sufficiently well shown by the numbers of times during the 45 years, 1884-1928, in which the individual months show agreements between the departures from normal of the Southern rainfalls and of the Darwin air pressures, counting agreement when lower barometer readings go with higher rainfall, and vice versa. Expressed in percentages of the possible number (45), these are as follow:—January, 55; February, 57; March, 53; April, 45; May, 67; June, 67; July, 71; August, 72; September, 64; October, 73; November, 72; December, 50.

With a view to rainfall prediction the Darwin pressure departures for each pair of months were compared with our Southern rainfalls for the following pair. Agreements, reckoned as above, resulted as follow:—

Darwin Pressure Departures		Northern Victorian Rainfall Departures	Percentage of Agreements p.c.
January-February	with	March-April	47
February-March	,,	April-May	50
March-April	,,	May-June	67
April-May	,,	June-July	76
May-June	,,	July-August	77
June-July	,,	August-September	82
July-August	,,	September-October	70
August-September	,,	October-November	71
September-October	,,	November-December	50
October-November	,,	December-January	55
November-December	,,	January-February	59
December-January	,,	February-March	56

which are actually better than the synchronous monthly agreements.

As the foregoing suggests, the best forecast results are got by using the Darwin June-July air pressures to indicate the Southern August-September rainfall. This is of economic importance, the August-September rainfall having almost a critical value in cereal production, as well as determining the state of Spring and Summer pastures. The graph, Figure 1, in which pressure departures are reversed, shows the remarkably consistent way in which our August-September rainfall follows the June-July Darwin pressure departures. These curves give the high correlation co-efficient of $-\cdot 79 \pm \cdot 038$. The proportionality between the extreme variations is good enough to suggest possibilities of forecasting drought or flood conditions.

Correlation of the June-July Darwin air pressures with the rainfalls of the three following months taken separately, gave co-efficients of $-\cdot 62$ with August, $-\cdot 58$ with September, and $-\cdot 29$ with October, which confirm the advisability of taking the months in pairs.

The following table gives the forecast relation between the successive two-monthly Darwin air pressure means and the Southern inland rains for the two months following:—

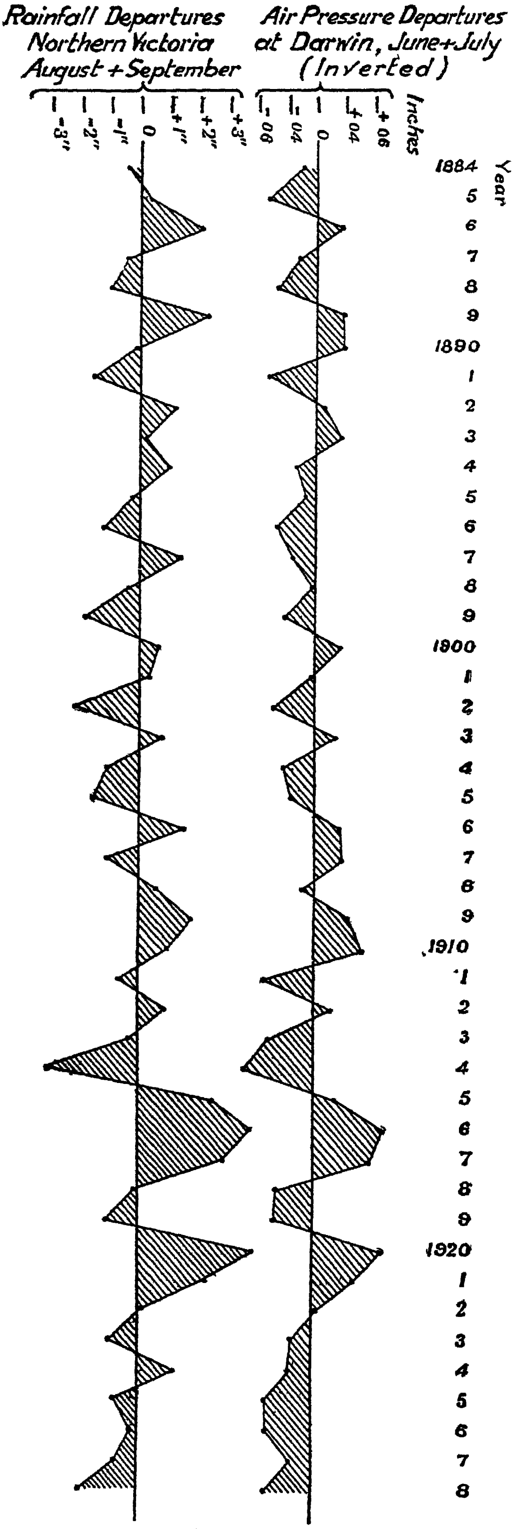
Rainfall Departures
Northern Victoria
August + September
Air Pressure Departures
at Darwin, June + July
(Inverted)
-3"
-2"
-1"
0
+1"
+2"
+3"
-.06
-.04
0
+.04
+.06
Inches
Year
1884
5
6
7
8
9
1890
1
2
3
4
5
6
7
8
9
1900
1
2
3
4
5
6
7
8
9
1910
1
2
3
4
5
6
7
8
9
1920
1
2
3
4
5
6
7
8

FIG. 1.

Pressure Departures at Darwin for		Rainfall over Northern Victoria for	Correlation Co-efficients.
March-April	with	May-June	—·15± ·098
April-May	„	June-July	—·39± ·085
May-June	„	July-August	—·65± ·057
June-July	„	August-September .	—·79± ·038
July-August	„	September-October	—·52± ·073
August-September	„	October-November .	—·37± ·088

In Figure 2, the August-September rainfalls for Northern Victoria (ordinate) are plotted against the Darwin air pressure departures (abscissa) for June-July. Each unit represents for the former one inch, for the latter ten-thousandths of an inch.

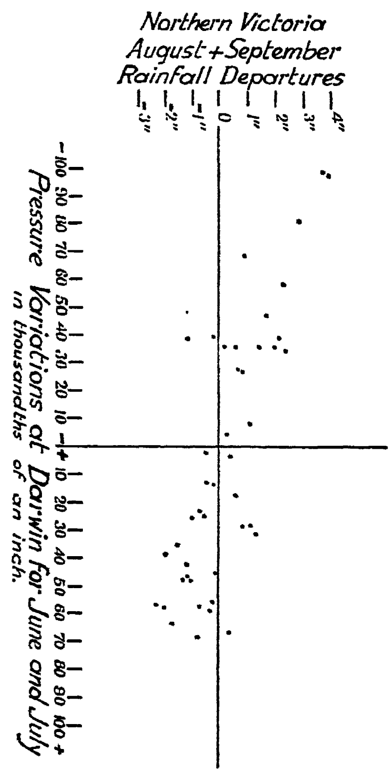

FIG. 2.

The proportionality between them is so well maintained that if we take the rainfall increase as nearly three-tenths of an inch for each one-hundredth of an inch fall in the monthly barometric mean at Darwin, we find for the 45 years under review that forecasts of the amount of rain so based upon the air pressures would have been less, or not more, than one inch in error on 35 occasions,

and over two inches in error on two occasions only. If it were necessary to say only whether the rainfall would be above or below average, the percentage of forecast accuracy would have been 82.

It is to be noted that the rainfall normals used for this paper are based upon the 30-year period, 1885-1914. By using the whole 45 years the principal correlation co-efficients are slightly improved by ·01, i.e., —·79 becomes —·80.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. XI.—*Solitary Waves at the Common Boundary of two liquids.*

By FRANCES E. ALLAN, M.A.

(Communicated by J. H. Michell).

[Read 11th October, 1928; issued separately 3rd April, 1929.]

The form and the velocity of solitary, or indefinitely long, waves in a single liquid have been examined experimentally by Scott Russell and mathematically by Boussinesq and Rayleigh. The much wider problem of the possible aperiodic wave forms at the common boundary of two superposed liquids does not seem to have received similar treatment. Those who have treated the subject of waves of finite height at the surface of separation of two liquids have dealt rather with the case of periodic waves, for which a different method is suitable. (Priestly, *Camb. Phil. Soc. Proc.*, 1910; Lamb, *ibid.*, 1922; Kolchine, *Math. Ann.*, 1927-8.)

The discussion here given follows the method used by J. H. Michell in unpublished work.

The motion is supposed two-dimensional, and will be treated as steady by choice of an origin of coordinates moving at the rate of the wave-form. The axis of x is taken horizontal and the axis of y directed upwards. The independent variables are changed from x, y to x, ψ where ψ is the stream function for the motion. This simplifies the treatment of the conditions over the boundaries, the coordinate ψ being constant over each of them. The dependent variable to be found in terms of x and ψ is now y, for which, therefore, a differential equation must be found. When y is found the form of a boundary is given in Cartesian coordinates by ascribing the corresponding constant value to ψ.

In carrying out the process of approximation we take as the general mathematical characteristic of the long-wave motion that the variation of a quantity specifying it (in particular, the gradient of the wave form), in a distance equal to the depth of either liquid, is a small fraction of the quantity itself. Thus, if we take the unit of length as of the order of magnitude of the depth of either liquid, the second derivative d^2y/dx^2 is to be a small fraction of dy/dx, and so for higher derivatives. The assumption is to include the smallness of dy/dx itself. The general discussion terminates in the expression of the gradient dy/dx of the wave form in terms of y. I have considered the conditions under which the gradient takes the factor form appropriate to either a crested or an inverted (trough) wave form. The expression of x in terms of y in general involves elliptic integrals of the third kind. Where the undisturbed depth of the lower liquid is small we may find an approximate

equation involving an elliptic integral of the first kind only to determine the form of the symmetric wave. I have dealt, finally, with a case of asymmetric wave (bore) where the gradient-equation for the form can be integrated without further approximation.

The Differential Equation for y.

In terms of independent variables x, y, the corresponding components of velocity are given by

$$u = -\partial\psi/\partial y,$$
$$v = \partial\psi/\partial x,$$

and the vorticity by

$$\omega = \partial^2\psi/\partial x^2 + \partial^2\psi/\partial y^2.$$

When the independent variables x, ψ, are introduced we have

$$v = \left(\frac{\partial\psi}{\partial x}\right)_{y\ \text{const.}}$$

$$= \frac{-\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}}, \text{when } y \text{ is a function of } x \text{ and } \psi,$$

and

$$u = -\left(\frac{\partial\psi}{\partial y}\right)_{x\ \text{const.}}$$

$$= -\frac{1}{\dfrac{\partial y}{\partial\psi}}, \text{when } \psi \text{ and } x \text{ are the independent variables.}$$

Also

$$\left(\frac{\partial v}{\partial x}\right)_{y\ \text{const.}} = \left(\frac{\partial v}{\partial x}\right)_{\psi\ \text{const.}} - \frac{\dfrac{\partial v}{\partial\psi}\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}},$$

and

$$\left(\frac{\partial u}{\partial y}\right)_{x\ \text{const.}} = \frac{\dfrac{\partial u}{\partial\psi}}{\dfrac{\partial y}{\partial\psi}}.$$

Therefore, as a function of x and ψ,

$$\omega = \frac{\partial v}{\partial x} - \frac{\dfrac{\partial v}{\partial\psi}\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}} - \frac{\dfrac{\partial u}{\partial\psi}}{\dfrac{\partial y}{\partial\psi}}.$$

Whence, substituting for u and v,

$$\omega = \left\{-\frac{\dfrac{\partial^2 y}{\partial x^2}}{\dfrac{\partial y}{\partial\psi}} + \frac{\dfrac{\partial y}{\partial x}\dfrac{\partial^2 y}{\partial x\partial\psi}}{\left(\dfrac{\partial y}{\partial\psi}\right)^2}\right\} + \left\{\frac{\dfrac{\partial^2 y}{\partial x\partial\psi}\dfrac{\partial y}{\partial x}}{\left(\dfrac{\partial y}{\partial\psi}\right)^2} - \frac{\dfrac{\partial^2 y}{\partial\psi^2}\left(\dfrac{\partial y}{\partial x}\right)^2}{\left(\dfrac{\partial y}{\partial\psi}\right)^3}\right\} - \frac{\dfrac{\partial^2 y}{\partial\psi^2}}{\left(\dfrac{\partial y}{\partial\psi}\right)^3},$$

that is,

$$-\omega\left(\frac{\partial y}{\partial \psi}\right)^3=\frac{\partial^2 y}{\partial x^2}\left(\frac{\partial y}{\partial \psi}\right)^2-2\frac{\partial y}{\partial x}\ \frac{\partial y}{\partial \psi}\ \frac{\partial^2 y}{\partial x\partial \psi}+\left\{1+\left(\frac{\partial y}{\partial x}\right)^2\right\}\frac{\partial^2 y}{\partial \psi^2}.$$

Therefore for irrotational motion, where $\omega=0$, we have

$$\frac{\partial^2 y}{\partial x^2}\left(\frac{\partial y}{\partial \psi}\right)^2-2\frac{\partial y}{\partial x}\ \frac{\partial y}{\partial \psi}\ \frac{\partial^2 y}{\partial x\,\partial \psi}+\left\{1+\left(\frac{\partial y}{\partial x}\right)^2\right\}\frac{\partial^2 y}{\partial \psi^2}=0. \quad (1)$$

To investigate a type of irrotational waves we must now find an approximate solution of this equation which will satisfy also the boundary conditions of the problem.

J. H. Michell has used this process as an alternative method of determining the well-known results for the infinitesimal and solitary long waves at the free upper surface of a liquid. The method applies equally well to problems on superposed liquids, and I have used it to find the equation to the form of the wave of finite height and wave length as far as the terms of the sixth order in the wave height.

The question to be considered here, however, is the form of the long wave at the boundary between two liquids in relative motion, the whole being confined between parallel planes at a distance h apart.

Let $y=0$, $y=h$ be the fixed horizontal planes between which the liquids lie. Let $\psi=0$ at $y=0$, $\psi=a$ at $y=h$ and $\psi=c$ at the interface of the liquids. Finally, let ρ, ρ' be the densities of the lower and upper liquids and U, V their respective "undisturbed" velocities.

At the first step in the approximate solution of the differential equation (1) for y, we neglect the first two terms as of the second order and the equation then reduces to

$$\frac{\partial^2 y}{\partial \psi^2}=0. \quad \text{.................................(2)}$$

On integration, this gives, for the lower liquid,

$$y=\eta\psi, \quad \text{.................................(3)}$$

where η is a function of x. (There is no term independent of ψ since $y=0$ when $\psi=0$.)

Substituting the value of y given by (3) in the second order terms of (1), and integrating again, we find

$$y+\tfrac{1}{6}\psi^3\left(\eta^2\frac{\partial^2\eta}{\partial x^2}-2\eta\overline{\frac{\partial\eta}{\partial x}}\Big|^2\right)=\eta\psi, \quad \text{.....................(4)}$$

and putting $y=\eta\psi$ in the second order terms of (4), we obtain

$$y+\tfrac{1}{6}\left(y^2\frac{\partial^2 y}{\partial x^2}-2y\overline{\frac{\partial y}{\partial x}}\Big|^2\right)=\eta\psi. \quad \text{.....................(5)}$$

Using the result

$$\eta=\frac{\partial y}{\partial \psi}+\tfrac{1}{2}\psi^2\left\{\eta^2\frac{\partial^2\eta}{\partial x^2}-2\eta\left(\frac{\partial\eta}{\partial x}\right)^2\right\},$$

and its consequence

$$\eta\psi = \psi\frac{\partial y}{\partial \psi} + \tfrac{1}{2}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\overline{\frac{\partial y}{\partial x}}\Big|^2\right\},$$

we can write (5) in the form

$$y - \tfrac{1}{3}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\overline{\frac{\partial y}{\partial x}}\Big|^2\right\} = \psi\frac{\partial y}{\partial \psi}. \quad \text{..................(6)}$$

For the upper liquid, when we integrate the equation $\partial^2 y/\partial\psi^2 = 0$ we get

$$y - h = \eta(\psi - a), \quad \text{.........................(7)}$$

since $y = h$ when $\psi = a$.

Following the same steps as in the case of the lower liquid we get the equation

$$y - h - \tfrac{1}{3}\left\{(y-h)^2\frac{\partial^2 y}{\partial x^2} - 2(y-h)\left(\frac{\partial y}{\partial x}\right)^2\right\} = (\psi - a)\frac{\partial y}{\partial \psi}. \quad \text{......(8)}$$

Since the pressure must be continuous across the interface, we deduce from Bernouilli's pressure equation the result

$$\rho q^2 - \rho' q'^2 = (A - 2gy)(\rho - \rho'), \quad \text{.... ....(9)}$$

for points on the interface, where q and q' are the velocities in the lower and upper liquids respectively at the point considered, and A is some constant.

But

$$q^2 = \frac{1 + \left(\dfrac{\partial y}{\partial x}\right)^2}{\left(\dfrac{\partial y}{\partial \psi}\right)^2},$$

and $\psi = c$, at the interface, so from (6) we find that at the interface

$$c\frac{\partial y}{\partial \psi} = y - \tfrac{1}{3}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\overline{\frac{\partial y}{\partial x}}\Big|^2\right\}$$

and therefore

$$q^2 = \frac{c^2\left\{1 + \left(\dfrac{\partial y}{\partial x}\right)^2\right\}}{y^2\left\{1 - \tfrac{1}{3}\left(y\dfrac{\partial^2 y}{\partial x^2} - 2\overline{\dfrac{\partial y}{\partial x}}\Big|^2\right)\right\}^2}$$

$$= \frac{c^2}{y^2}\left\{1 + \tfrac{2}{3}y\frac{\partial^2 y}{\partial x^2} - \tfrac{1}{3}\overline{\frac{\partial y}{\partial x}}\Big|^2\right\}, \quad \text{....................(10)}$$

and in a similar way we find

$$q'^2 = \frac{(c-a)^2}{(y-h)^2}\left\{1 + \tfrac{2}{3}(y-h)\frac{\partial^2 y}{\partial x^2} - \tfrac{1}{3}\left(\frac{\partial y}{\partial x}\right)^2\right\}. \quad \text{........(11)}$$

Hence (9) becomes

$$\frac{\rho c^2}{y^2} - \frac{\rho'(c-a)^2}{(y-h)^2} + \tfrac{2}{3}\left\{\frac{\rho c^2}{y} - \frac{\rho'(c-a)^2}{(y-h)}\right\}\frac{\partial^2 y}{\partial x^2} -$$

$$-\tfrac{1}{3}\left\{\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}\right\}\left(\frac{\partial y}{\partial x}\right)^2=(A-2gy)(\rho-\rho'), \quad (12)$$

and this is the differential equation for the form of the interface. We may write it

$$\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}+\tfrac{1}{3}\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\frac{d}{dy}\left(\frac{dy}{dx}\right)^2$$
$$-\tfrac{1}{3}\left\{\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}\right\}\left(\frac{dy}{dx}\right)^2=(A-2gy)(\rho-\rho'), \quad \text{.........}(13)$$

that is,

$$\frac{d}{dy}\left[\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\left(\frac{dy}{dx}\right)^2\right]=3(A-2gy)(\rho-\rho')-\frac{3\rho c^2}{y^2}+3\rho'\frac{(c-a)^2}{(y-h)^2}. \quad \text{............}(14)$$

Integrating this we obtain

$$\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\left(\frac{dy}{dx}\right)^2=3(Ay-gy^2)(\rho-\rho')+\frac{3\rho c^2}{y}+\frac{3\rho'(c-a)^2}{y-h}+D, \quad \text{............}(15)$$

where D is a constant of integration.

Thus

$$\left(\frac{dy}{dx}\right)^2=\frac{\{D+By-3g(\rho-\rho')y^2\}y(y-h)+3\rho c^2(y-h)-3\rho'(c-a)^2y}{\rho c^2(y-h)-\rho'(c-a)^2y}, \quad \text{............}(16)$$

where $3A(\rho-\rho')=B$.

This is the expression found by J. H. Michell for the gradient. We now assume that this expression will factorize in such a manner as to give the desired wave form, and then consider the further conditions which will make such a form possible. That is, we suppose

$$\left(\frac{dy}{dx}\right)^2=\frac{-3g(\rho-\rho')(y-k)^2(y-k_1)(y-k_2)}{\rho c^2(y-h)-\rho'(c-a)^2y}. \quad \text{............}(17)$$

This makes $dy/dx=0$ and $d^2y/dx^2=0$ when $y=k$; and $dy/dx=0$ when $y=k_1$, and when $y=k_2$.

Thus with this form the condition that the surface may be horizontal when $y=k$, is satisfied.

Now for (16) to be equivalent to (17) we must have, by equating coefficients of y,

$$k^2k_1k_2=\frac{\rho c^2h}{g(\rho-\rho')}, \quad \text{.........................}(18)$$

$$3g(\rho-\rho')\{2kk_1k_2+k^2(k_1+k_2)\}=-Dh+3\{\rho c^2-\rho'(c-a)^2\}, \quad \text{..}(19)$$

$$-3g(\rho-\rho')\{k^2+2k(k_1+k_2)+k_1k_2\}=D-Bh, \quad \text{....................}(20)$$

$$3g(\rho-\rho')\{2k+k_1+k_2\}=B+3gh(\rho-\rho'), \quad \text{.........................}(21)$$

and from these equations (18)-(21) we deduce :—

$$k_1+k_2=\frac{\rho c^2}{k^2g(\rho-\rho')}-\frac{\rho'(c-a)^2}{(h-k)^2g(\rho-\rho')}+h, \quad \text{...........}(22)$$

$$\text{and } k_1 k_2 = \frac{\rho c^2 h}{k^2 g(\rho - \rho')}, \quad \text{.......................(23)}$$

so that k_1, k_2 are the roots of the equation

$$a^2 - \left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\} a + \frac{\rho c^2 h}{k^2 g(\rho - \rho')} = 0. \quad \text{...(24)}$$

We therefore have

$$2k_1 = h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')}$$
$$- \sqrt{\left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\}^2 - \frac{4\rho c^2 h}{k^2 g(\rho - \rho')}},$$

$$2k_2 = h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')}$$
$$+ \sqrt{\left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\}^2 - \frac{4\rho c^2 h}{k^2 g(\rho - \rho')}}.$$

We may write

$$\frac{c^2}{k^2} = U^2 \quad \text{and} \quad \frac{(c-a)^2}{(h-k)^2} = V^2,$$

since U is the velocity at infinity of the undisturbed lower liquid of depth k, and V is the velocity at infinity of the undisturbed upper liquid of depth $(h-k)$.

If we also write $\rho' = \lambda\rho$ and $V^2 = \mu U^2$ we have :—

$$2k_1 = h + \frac{U^2}{g(1-\lambda)}(1-\lambda\mu) - \sqrt{\left\{ h + \frac{U^2(1-\lambda\mu)}{g(1-\lambda)} \right\}^2 - \frac{4hU^2}{g(1-\lambda)}},$$

$$2k_2 = h + \frac{U^2}{g(1-\lambda)}\left\{ 1 - \lambda\mu \right\} + \sqrt{\left\{ h + \frac{U^2(1-\lambda\mu)}{g(1-\lambda)} \right\}^2 - \frac{4hU^2}{g(1-\lambda)}}.$$

Necessary Conditions for such a Wave.

We have put the equation for the gradient into the form

$$\left(\frac{dy}{dx}\right)^2 = \frac{3g(1-\lambda)(y-k)^2(y-k_1)(y-k_2)}{U^2[k^2 h - \{ k^2 - \lambda\mu(h-k)^2 \} y]}.$$

Now the denominator may be written $k^2(h-y) + \lambda\mu(h-k)^2 y$ and y is less than h at all points on the interface. Therefore the denominator is always positive. Hence, assuming $\lambda < 1$ (*i.e.*, $\rho' < \rho$), we must have $y - k_1$ and $y - k_2$ of the same sign, to make dy/dx real.

But y lies between k and either k_1 or k_2, since k, k_1, and k_2 are the turning values of y. Therefore, either

(i) $k < y < k_1 < k_2$,

or (ii) $k > y > k_2 > k_1$.

These alternatives represent

(i) a crested wave,

or (ii) an inverted wave.

There is no wave for a value of k between k_1 and k_2.

Thus, for values of k between 0 and k_1 there is a crested wave, and for values of k between k_2 and h there is an inverted wave.

Lamb has treated the infinitesimal wave at the interface between two liquids (see Lamb's Hydrodynamics, Arts. 231-234), and if in Lamb's result we make the wave length tend to infinity, we find, as we should expect, that the two heights at which infinitesimal long waves are possible are k_1 and k_2.

Now, since k_1 will be the height of the crest when a crested wave exists and k_2 will be the depth of the lower liquid at the trough in the case of an inverted wave, it will be necessary for k_1 and k_2 to be real if there is to be a wave form at all. Therefore, referring to the equation (24), we deduce the condition

$$\left\{h + \frac{U^2(1-\lambda\mu)}{g(1-\lambda)}\right\}^2 \nless \frac{4hU^2}{g(1-\lambda)}.$$

Approximation-Method for High Waves.

If we take k very small we find approximately

$$\left(\frac{dy}{dx}\right)^2 = C\frac{y(y-2k)(y-k_1)(y-k_2)}{y}$$
$$= C(y-2k)(y-k_1)(y-k_2),$$

for values of y near the crest, where C is a known constant. This makes

$$\sqrt{C}\,x = \int \frac{dy}{\sqrt{(y-2k)(y-k_1)(y-k_2)}}.$$

Hence we can find an approximate form for the wave in terms of an elliptic integral when the wave is near its greatest height.

The Asymmetric Long Wave.

There is, however, a type of long wave whose form can be determined from the differential equation without further approximation. This is the wave which we get on putting $k_1 = k_2$. Its differential equation is

$$\left(\frac{dy}{dx}\right)^2 = \frac{3g(1-\lambda)(y-k)^2(k_1-y)^2}{U^2[k^2h - \{k^2 - \lambda\mu(h-k)^2\}y]},$$

and therefore when $y=k$, or $y=k_1$, $dy/dx=0$, and $d^2y/dx^2=0$.

This means that the wave has no crests but rises gradually, through an infinite horizontal distance from $y=k$ to $y=k_1$. The motion is here of the nature of a "bore."

Since k_1 and k_2 are the roots of equation (24), the condition that k_1 should be equal to k_2 is

$$\left\{\frac{\rho c^2}{h^2 g(\rho-\rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho-\rho')} + h\right\}^2 = \frac{4\rho c^2 h}{g(\rho-\rho')h^2}, \quad \text{.........(25)}$$

that is,

$$\left\{\frac{U^2}{g(1-\lambda)}-\frac{V^2\lambda}{g(1-\lambda)}+h\right\}^2=\frac{4U^2h}{g(1-\lambda)}. \qquad \text{.................(26)}$$

This gives

$$h^2-\frac{2}{g(1-\lambda)}(U^2+\lambda V^2)h+\frac{(U^2-\lambda V^2)^2}{g^2(1-\lambda)^2}=0, \qquad \text{...........(27)}$$

and the roots of this are always real, since $(U^2+\lambda V^2)^2>(U^2-\lambda V^2)^2$. This means that for any given pair of values of the velocities U, V, of the currents, there are two possible values of h, the distance apart of the horizontal boundaries; they are given by

$$h=\frac{1}{g(1-\lambda)}(U\pm\sqrt{\lambda}V)^2. \qquad \text{....................(28)}$$

If we regard equation (26) as an equation for V in terms of h and U we find

$$|V|=\frac{U\pm\sqrt{gh(1-\lambda)}}{\sqrt{\lambda}} \qquad \text{.......................(29)}$$

When condition (26) is satisfied, we have, from (22)

$$k_1=k_2=\tfrac{1}{2}\left\{h+\frac{U^2}{g(1-\lambda)}-\frac{V^2\lambda}{g(1-\lambda)}\right\}, \qquad \text{.................(30)}$$

and on substituting for V from equation (29) we deduce

$$k_1=h\sqrt{\frac{U^2}{gh(1-\lambda)}}. \qquad \text{.......................(31)}$$

The positive sign with the root in (29) would give

$$k_1=-h\sqrt{\frac{U^2}{gh(1-\lambda)}},$$

and we consider, therefore, only the negative sign. That is, we take

$$\lambda V^2=U^2\left\{1-\frac{\sqrt{(1-\lambda)gh}}{U}\right\}^2$$

$$=U^2\left(\frac{h}{k_1}-1\right)^2.$$

Now, returning to the equation for $(dy/dx)^2$, these results give

$$(dy/dx)^2=\frac{3g(1-\lambda)}{U^2}\;\frac{(y-k)^2(k_1-y)^2}{[hk^2-\{k^2-(h-k)^2(1-h/k_1)^2\}y]}$$

$$=\frac{3g(1-\lambda)k_1^2}{U^2h}\;\frac{(y-k)^2(k_1-y)^2}{[k^2k_1^2-\{k_1^2-(h-k)^2(h-k_1)^2\}y/h]}$$

$$=\frac{3(y-k)^2(k_1-y)^2}{[k^2k_1^2-\{k^2k_1^2-(h-k)^2(h-k_1)^2\}y/h]}.$$

Three cases now arise, depending on whether

(i) $kk_1=(h-k)(h-k_1)$,
(ii) $kk_1>(h-k)(h-k_1)$,
(iii) $kk_1<(h-k)(h-k_1)$.

We shall now consider these separately.

(i) Here we have $kk_1=(h-k)(h-k_1)$
and, therefore, $k+k_1=h$.
This means that the highest and lowest levels of the wave are equidistant from the mean height $h/2$ of the liquids.
In this case

$$\left(\frac{dy}{dx}\right)^2=\frac{3(y-k^2)(k_1-y^2)}{k^2k_1^2},$$

and therefore

$$\frac{dy}{dx}=\frac{\sqrt{3}}{kk_1}(y-k)(k_1-y),$$

where y lies between k and k_1.

On integrating, if we choose the origin so that the constant of integration is zero, we find

$$\frac{\sqrt{3}}{kk_1}x=\int\frac{dy}{\left(\frac{k_1-k}{2}\right)^2-\left(y-\frac{k+k_1}{2}\right)^2}$$

$$=\frac{2}{k_1-k}\ \operatorname{artanh}\frac{y-\frac{k+k_1}{2}}{\frac{k_1-k}{2}}.$$

Now changing over to a horizontal axis along the mean level, so that $y'=y-\frac{k+k_1}{2}$, we find the equation to the wave form is

$$\frac{k_1-k}{kk_1}\,\frac{\sqrt{3}}{2}x=\operatorname{artanh}\frac{2y'}{k_1-k},$$

that is, $y'=a\tanh mx$,

where $a=\dfrac{k_1-k}{2}$,

$$m=\frac{\sqrt{3}}{2}\left(\frac{1}{k}-\frac{1}{k_1}\right).$$

(ii) Consider now the case $kk_1>(h-k)(h-k_1)$.
Here

$$\left(\frac{dy}{dx}\right)^2=\frac{3(y-k)^2(k_1-y)^2}{[k^2k_1^2-\{k^2k_1^2-(h-k)^2(h-k_1)^2\}y/h]}$$

$$\doteq\frac{\alpha^2(y-k)^2(k_1-y)^2}{\beta^2-y},$$

where $\alpha^2 = \dfrac{3h}{k^2k_1^2 - (h-k)^2(h-k_1)^2}$ and $\beta^2 = \dfrac{k^2k_1^2}{3}\alpha^2$.

Now, since $kk_1 > (h-k)(h-k_1)$,
therefore $h < k + k_1$,
and therefore $h - k < k_1$ and $h - k_1 < k$.

But
$$\beta^2 = \frac{k^2k_1^2h}{k^2k_1^2 - (h-k)^2(h-k_1)^2}$$
$$= \frac{h}{1 - \dfrac{(h-k)^2(h-k_1)^2}{k^2k_1^2}}$$
$$= \frac{h}{1-\theta}, \text{ where } 0 < \theta < 1.$$

Therefore $\beta^2 > h$,
$> k_1$,
$> k$.

Now $\dfrac{dx}{dy} = \dfrac{1}{\alpha}\dfrac{\sqrt{\beta^2 - y}}{(y-k)(k_1-y)}$, therefore

$$(k_1 - k)\alpha x = \int \frac{\sqrt{\beta^2 - y}}{y-k}\,dy + \int \frac{\sqrt{\beta^2 - y}}{k_1 - y}\,dy$$
$$= -2\sqrt{\beta^2 - k}\ \text{artanh}\ \frac{\sqrt{\beta^2 - y}}{\sqrt{\beta^2 - k}} + 2\sqrt{\beta^2 - k_1}\ \text{arcoth}\ \frac{\sqrt{\beta^2 - y}}{\sqrt{\beta^2 - k_1}},$$

which is the equation to the wave form in this second case.

(iii) If $kk_1 < (h-k)(h-k_1)$,

$$(dy/dx)^2 = \frac{\alpha^2(y-k)^2(y-k_1)^2}{\beta^2 + y},$$

where $\alpha^2 = \dfrac{3h}{(h-k)^2(h-k_1)^2 - k^2k_1^2}$,

and $\beta^2 = \dfrac{k^2k_1^2}{3}\alpha^2$.

Therefore $\dfrac{dx}{dy} = \dfrac{1}{\alpha}\dfrac{\sqrt{\beta^2 + y}}{(y-k)(k_1-y)}$, and

$$\alpha x = \int \frac{\sqrt{\beta^2 + y}}{(y-k)(k_1-y)}\,dy$$
$$= \int \sqrt{\beta^2 + y}\left\{\frac{1}{y-k} + \frac{1}{k_1 - y}\right\}\frac{1}{k_1 - k}\,dy.$$

Therefore

$$(k_1-k)\alpha x=2\sqrt{k_1+\beta^2}\ \operatorname{artanh}\frac{\sqrt{y+\beta^2}}{\sqrt{k_1+\beta^2}}-2\sqrt{k+\beta^2}\ \operatorname{arcoth}\frac{\sqrt{y+\beta^2}}{\sqrt{k+\beta^2}}.$$

The present paper embodies a small portion of the work done under the terms of a Research Grant for Mathematics in the University of Melbourne. The publication of the rest of the work has been postponed owing to the author's departure for England.

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ART. XII.—*The Geology and Palaeontography of the Cathedral Range and the Blue Hills, in North-Western Gippsland.*

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(With Plates XVII, XVIII.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

Summary.

1. The Cathedral Beds, formerly believed to be of Upper Palaeozoic age, are demonstrated to be of pre-Upper Devonian, and probably of Upper Silurian age.
2. The western edge of the large area of igneous rocks which contains Mt. Torbreck and the Cerberean Ranges, is shown to consist of Upper Devonian rocks, mainly rhyolites, and these are shown to occur to an unknown extent to the east.
3. A newly discovered fish fauna from the Upper Devonian is described.
4. Silurian fossils from a new locality are listed, and a new stelleroid noticed.

Introduction.

LOCATION.

The area studied is a roughly rectangular block of country stretching, along its western boundary, from Buxton to Taggerty, a distance of seven miles. It extends eastwards for five and a half miles from Taggerty, and three and a half miles from Buxton, and consists mainly of the southern two-thirds of the Parish of Taggerty, in the County of Anglesea.

The location was suggested in December, 1927, by Professor Skeats, as likely to reveal the relations between the Cathedral Beds (supposed Upper Devonian or Lower Carboniferous), and the dacites (supposed Lower Devonian).

The latter are, however, not present in the area, and the Cathedral Beds appear to be Silurian in age, while the supposed dacites are Upper Devonian rhyolites.

PREVIOUS WORKERS.

The amount of previous work done in this area is extremely small. In 1899 W. H. Ferguson reported as follows after a very rapid examination: "The rocks are layers of coarse and moderately

coarse-grained sandstones, with some shales . . . the sandstones . . . contain a few well waterworn pebbles. . . . Ripple markings and filled-in desiccation cracks were noted. In some of the coarse-grained sandstones spots of very fine sedimentary rock were seen. . . . No fossils were found in the sandstones of the Cathedral Mountain, which is three or four miles in length. The rocks near this mountain are Upper Silurian porphyries, slates and sandstones. No clear contact could be found showing the relation of the Silurian rocks to the Cathedral sandstones, but the general lithological inference is that the Cathedral rocks are younger than the Silurian, and probably of Upper Palaeozoic age, Upper Devonian or Lower Carboniferous. On the east the sandstones join the fragmental porphyry formation at the Little River. These rocks, in other parts of the colony, have been referred to Upper Palaeozoic age." (Ferguson, 1899).

On this evidence, the Cathedral sandstones were coloured as Upper Palaeozoic on the Geological Map of Victoria, an inch to 8 miles, published later by the Survey.

Professor J. W. Gregory probably visited the area, and he published his idea of the structure in his handbook on the Geography of Victoria (Gregory, 1912, p. 72), showing the Cathedral sandstones as older than the volcanic rocks, which he believed to be dacites, and thought to be of Tertiary age. A rock section [400] at the Geology School is labelled "Dacite: Between Chapel Hill and the Cerbereans," and was probably collected by him. It is not, however, a dacite, but a section of the main rhyolite flow.

Professor Skeats (1910) writes, following Gregory:—"The map indicates a great mass of granitic rocks extending from near Narbethong, through Marysville, north-east to Mount Torbrech, whereas over most of this area the rock is certainly dacite." The granitic rock at Buxton is coloured as such by the Survey. The only other relevant record of geological work the author could find is a report by Dunn (1907) on gold and tin workings just outside the area here considered, and dealing with Silurian sediments only.

Physical Features.

The area is one of strong, even precipitous, relief. The Cathedral Range runs in a general SSE. direction from the Cathedral to the Sugarloaf (see map), and is a composite hogback grading to a razorback, with the dip slopes (often bare sandstone) to the east, and the escarpment on the west. There the slopes are covered with thick talus, and in profile this presents a curve of great beauty.

The crest of the range is determined by the outcrops of two beds of hard sandstone, extending the whole seven miles, and separated by soft shales. At the northern end the highest ridge, with the Cathedral Mount, is formed by the lower standstone, while in the south the highest ridge, with the Sugarloaf, is formed by the

upper sandstone dipping easterly at 65°, and constituting a razor-back. The trough-shaped subsequent valley between the sandstones is called the Tableland. It is well grassed, and is used as a sheep run.

In the valley west of the Cathedral Range the Acheron River flows northwards to the Goulburn, while the valley east of that Range is occupied by the Little River, flowing north-north-west and later west to join the Acheron at Taggerty. The western boundary of the area studied is marked by the crestline of the Blue Hills, a range higher than the Cathedral Range, running generally NNE.-SSW. The slopes of this range are covered with rounded rhyolite boulders in the upper parts, but become clearer on the Silurian lower down. Chapel Hill lies in the traingle between the Little River and the Blue Hills. Immediately to the east of Buxton a resistant granodiorite-porphyrite has determined the formation of a steep and, especially at its southern end, high ridge. The river flats are swampy.

Nature of the Present Survey.

The combination of steep bouldery slopes, sometimes precipitous, dense growths of bracken, and in the gullies, tangled fern flora, made the work of surveying without a companion both arduous and difficult. The boundary of the Upper Devonian north-east of the Little River, the Buxton granodiorite, the Little River alluvium (where shown on the map), and a small but important area east of the Sugarloaf were traversed by compass, distances being paced. The Cathedral Beds were mapped approximately by radiations from fixed points on the main road, in the absence of a reliable method of measuring distances up steep slopes, and the talus from the Cathedral Range was marked in from sketches of the range. The outcrops on Chapel Hill, the talus from the Blue Hills, and the boundary of the Silurian to the east of Buxton, were sketched in from a knowledge of the country from memory, with the help of notes and sketches. The Lands Department's parish plans on a scale of 2 inches to the mile were used as the basis for all work.

Geology.

Yeringian (Upper Silurian).

1. *Typical Silurian.*

Shallow marine Silurian mudstones, sandstones and shales occur both in the north and the south. Fossils were found near the foot of the Blue Hills, in red sandstones showing miniature current bedding due to ripple-mark. The fossils are for the most part fragmental, and occur in small groups, suggesting re-sorting along a beach or on a sandbar. The following forms have been identified (the last four by Mr. Chapman) :—

Anthozoa.	*Cladopora* sp.
Asterozoa.	*Taeniaster* (?), sp. nov. aff. *spinosus* Billings.
Brachiopoda.	*Orthis* (*Dalmanella*) *testudinaria* Dalman.
	Chonetes sp.
	cf. *Coelospira* sp.
Pteropoda.	*Coleolus* cf. *aciculum* J. Hall.
Cephalopoda.	*Orthoceras* sp.

The assemblage, especially *Cladopora* and *Dalmanella,* which are characteristic, indicates that the beds are Yeringian (Upper Silurian) in age. Indeterminate fragments of plants were found in several places along the Little River east of Taggerty. No fossils were found in the south near Buxton, but the Silurian rocks are apparently continuous on the west side of the Acheron from Taggerty to Buxton, as is shown on the Geological Survey's map, and in part confirmed by Dunn (1907). The beds are lithologically quite similar in the north and the south.

In the north the fossiliferous beds are overlain unconformably by the Upper Devonian, and are faulted against the Cathedral Beds along an east-west fault line. This fault is pre-Upper Devonian, beds of that age not being displaced by it. In the south the relations with the Cathedral Beds are different, the two apparently forming a conformable series. The Buxton granodiorite-porphyrite (? Lower Devonian) is intruded, perhaps as a sill, into the typical Silurian sediments, which are only slightly metamorphosed. Quartz veins, in part auriferous, are associated with the granodiorite.

On the north side of the Little River, the dip is 58° to the south-south-west, and the same dip and strike were found in a small creek just to the north of the fault, on the northern slopes of the Cathedral Range. No other outcrops were found where a definite dip could be obtained (see, however, p. 180).

2. *The Cathedral Beds.*

The rocks—hard sandstones, soft sandstones, and shales—which constitute the Cathedral Range and Chapel Hill, form a triangular outcrop between the Blue Hills and the Acheron Valley, ending abruptly in the north against a fault line. On the evidence before cited (see p. 177), they were previously regarded as of Upper Palaeozoic age.

Field Relations.

Ferguson could find ". . . no clear contact . . . showing the relation of the Silurian rocks to the Cathedral sandstones." Furthermore he says, "On the east the sandstones join the fragmental porphyry formation at the Little River."

(*a*) At their northern termination the Cathedral Beds are brought against the typical Silurian rocks by an east-west fault. Huge monoliths of crushed and shattered sandstone occur along

the fault line, and the strikes are locally contorted. The evidence of faulting may be traced a short distance to the east before being covered by talus, and the further extension of the fault to the east is inferred from the abrupt termination of the Cathedral Beds along the east-west line. Evidence as to the hade is indefinite, but the general dip of the Cathedral Beds (especially on Chapel Hill away from the fault line may indicate that the downthrow is to the south. No indication of displacement of the Upper Devonian beds by this fault was seen.

(*b*) East of Buxton, the relations are different. Traversing eastwards from Buxton, we notice that

1. The typical Silurian beds are intruded by the granodiorite-porphyrite.

2. The Silurian can be traced without apparent break to the foot of the Blue Hills, and there the dip and strike are the same as those of the Cathedral sandstones which occur close by, and have the same relations to the Upper Devonian as does the typical Silurian. The following observations are significant:—

(*a*) $1\frac{1}{2}$ miles W.20°N. from Buxton, the Silurian beds strike N.32°W. dip 40° westerly (Dunn, 1907). Compare

(*a'*) About a mile northwards along the Cathedral Range from the Sugarloaf, Cathedral Beds strike N.25°W. dip easterly at 60°.

(*b*) 3 miles E.10°S. of Buxton, the Silurian beds strike N.30°W. dip easterly at 70° (Dunn, 1907). Compare

(*b'*) Southern end of the Cathedral Range, Cathedral Beds strike N.35°W. dip 65° easterly. Furthermore, the Cathedral Range shows a marked parallelism with the trend lines in the Silurian in the southern part of the area, where no faulting occurs.

3. Just east of the Sugarloaf, in a small creek, the relations between the Cathedral beds and the Upper Devonian rhyolites can be clearly seen. The latter, striking N.25°E., and dipping at 30° easterly, overlie the Cathedral Beds, striking N.35°W., dipping 65° easterly, with a strong unconformity. The basal conglomerate, though developed further north, is absent here; but that we are dealing with the base of the rhyolite is shown by the well-developed prismatic jointing, which disappears higher up in the flow, the numerous linearly arranged sandstone inclusions which lessen in number and lose their linear arrangement higher up, and the slightly vesicular nature of the flow, which elsewhere is devoid of vesicles. Further, there is no contortion of strikes or brecciation in the Cathedral sandstones, such as are found where these beds are faulted in the north. Similar relations hold everywhere at the edge of the Upper Devonian series, being especially well shown south-east of Chapel Hill, where the characteristic oscillation ripple-marked sandstones are overlain by the Upper Devonian basal conglomerate.

The pre-Upper Devonian age of the Cathedral Beds is thus established, and their conformability with the Silurian strongly

indicated. In the absence of palaeontological evidence as to their more precise age, the author has placed them high in the Upper Silurian series.

Lithology.

Ferguson's original description is in the main correct, though, even after extensive search, the present author could find none of the " well-waterworn pebbles " mentioned by him, the largest particles found being only a few millimetres in diameter. The sandstones are very thick-bedded, and where not cross-bedded, are even-grained. The jointing is somewhat irregular, curved cracks often forming in the thick, even beds. When not strongly weathered the sandstones are red, but leaching of the outer few millimetres of weathered blocks produces a white skin. Ripple-markings, mud-cracks, current-bedding, and hardened clay pellets were found.

Along the Cathedral Range, subaqueous current ripple-marks occur, rarely. On Chapel Hill, however, ripple-marks of symmetrical shape, and formed by wave action (oscillation ripple-marks), occur in profusion in fine sandstones of lighter colour than the Cathedral sandstones. At some horizons the successive ripple-marked layers are separated by only fractions of an inch, and the lengths of the ripples from crest to crest (wave-length) remain fairly constant, averaging a little over an inch. The direction of propagation of the water waves which produced the ripples remained fairly constant, also. Examples were found of superimposition of the ripples in parallel and slightly inclined directions. No current-ripples (asymmetric) were found on Chapel Hill.

Mud-cracks are rare, but were found at the Sugarloaf, the north end of the Cathedral Range, and on Chapel Hill. The former two examples are in very fine, indurated sediment, a thin parting between heavy sandstones. The polygons are small, about six or eight inches across. The latter example (Chapel Hill) is in a thick sandy mud bed, which is cracked to a depth of about eighteen inches, the polygons ranging up to fifteen inches across. The edges are here turned down conspicuously.

Sandstones showing current-bedding were found at the Sugarloaf, but nowhere else. The current-bedded layers are usually bounded by plane surfaces, though a very few show curved boundaries. The slopes are fairly steep, especially in the thicker beds, whose thickness is up to three feet between the bounding planes.

Inclusions of very fine sediments similar to the material of the mud-cracked layers on the Cathedral Range are common there, but are absent in the oscillation ripple-marked sandstones of Chapel Hill. They probably represent clay pellets rolled into the sands by current action.

The interbedded soft sandstones and shales are grass-covered, and the only outcrops are blocks in the roots of fallen trees. The

bed separating the two sandstones of the Cathedral Range is a soft chocolate sandstone, and differs from the more yellowish shales of Chapel Hill. No fossils were found in any of the Cathedral Beds.

The Cathedral Beds differ from the Upper Palaeozoic rocks with which they were formerly included, in the absence of the conglomerates which are so characteristic of the latter, as described by Howitt (1876), Murray (1877), Kitson (1899), and Teale (1920), the absence of interbedded lavas, and the absence of fossils. They also dip at a much greater angle than the Upper Palaeozoic rocks, except where these are faulted. The author considers that much more detailed work than was possible in the time available will be necessary to elucidate the very interesting question of the conditions under which the Cathedral Beds were deposited. He would point out, however, that—

1. The Chapel Hill beds resemble somewhat the Berea sandstones of North America in the profuse development of the oscillation type of ripple-mark, with a generally constant direction of propagation, the absence of current ripples, and the lack of fossils (Hyde, 1919).

2. The Chapel Hill and the Cathedral beds were not deposited under exactly the same conditions, as is shown by their different physical characteristics (see above).

3. In the Grampians sandstones, a thick series in which no fossils were found for many years, the few remains now known indicate a marine origin for the beds in which they occur (Chapman, 1917).

4. The absence of cut-and-fill structures and coarse materials, and the scarcity of muds and sun-cracked layers, as well as the extent and thickness of the beds, are against either a flood-plain or sub-aerial deltaic origin.

(?) Lower Devonian.

Intruded into the Silurian sediments at Buxton and to the east of Taggerty is a granodiorite-porphyrite, which is placed in the Lower Devonian by analogy with the other Victorian granodiorites, which are supposed to be of this age. Such granodiorites occur near Marysville, to the south of the occurrence at Buxton. The latter is much more extensive than the outcrop at Taggerty, being a long and narrow outcrop traced for two miles in a NNW. direction, and continuing still further to the southwards. The obvious relation of its outcrop to the trend of the Silurian near by, and its long, narrow outcrop, have led the author to believe that it may be a sill. The amount of metamorphism of the adjacent sediments is but slight, being merely an induration, with some silicification and development of muscovite. Quartz veins are associated with this intrusion, and these have proved auriferous to the south of the area considered.

The occurrences at Taggerty are very small, perhaps offshoots from a larger concealed mass. Of note is the occurrence in these

rocks of numerous pink garnets, sometimes showing dodecahedral outlines but more often rounded by reaction with the magma. Cognate (basic) and foreign xenoliths also occur.

Upper Devonian.

Beds of this age were discovered, forming the top of the Blue Hills and the ranges east of the Sugarloaf, and formerly believed to be Lower Devonian dacites. The main development is a series of acid lavas (rhyolites) of undetermined thickness, which outcrop along the whole of the eastern boundary of the area studied. Basalts and sediments also occur. There are numerous flows, the lower ones being interbedded with fossiliferous lacustrine and fluviatile deposits of limited areal extent; but the main rhyolite is recognisable continuously for over seven miles along its western edge, and the further extent to the south was not determined. Through the courtesy of the Director of the Victorian Geological Survey, Mr. Baragwanath, and his officers, the author had the privilege of examining some specimens collected by Mr. O. A. L. Whitelaw from the Mount Torbreck region, some nine miles to the east of the Blue Hills. The specimens proved to be of extreme interest, as they revealed the presence of exactly similar rhyolites, both in hand specimen and under the microscope, in that area, associated with typical dacites (as developed near Healesville, in the Dandenong Ranges, and at Mount Macedon) of supposed Lower Devonian age. A porphyritic granitic rock, very similar to that found at Buxton, is also in close proximity. The problems of the extent of the rhyolites and their relations to the granitic rocks are thus opened up.

A generalized sequence of the Upper Devonian is as follows:—

6. Rhyolite α (main flow, very thick).
5. Rhyolite β (small flow, in the north).
4. Basalt (in the north and south only).
3. Sediments (sandstones and shales in the north, bedded tuffs and volcanic breccias in the south).
2. Basal rhyolite.
1. Basal conglomerate (in the north).

The absence of the basal beds in places is due to their development only in the valleys of the Upper Devonian land surface.

They are overlapped by the main rhyolite flow, and where this rests on the Silurian directly, the upper Devonian land was high, so that the Sugarloaf was probably an upstanding peak then, as now (see Section E.-F., Fig. 1).

1. *The Basal Conglomerate.*

This extends uninterruptedly for nearly four miles along the Blue Hills, east of Chapel Hill. It is rather variable in thickness, reaching a maximum of about ten feet in the central part, and thinning out towards the north and south, where it is absent. The

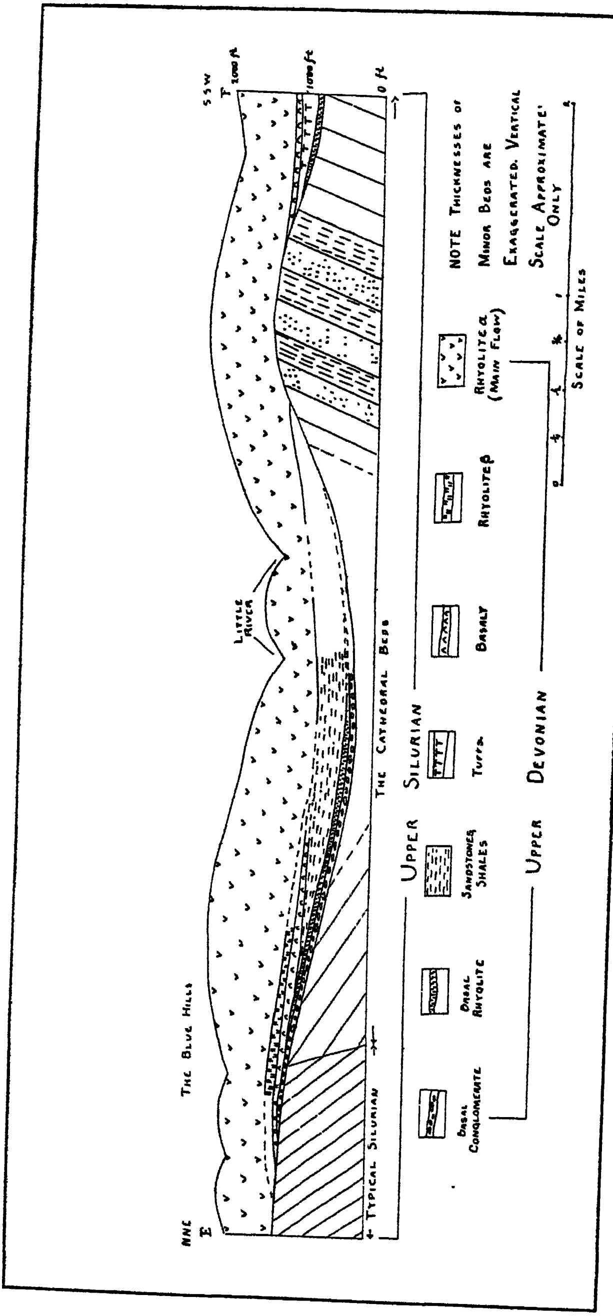

FIG. 1.—Diagrammatic section along the crest of the Blue Hills, parallel to the edge of the Upper Devonian outcrop.

coarseness varies in a like manner, the boulders in the centre being larger than elsewhere, reaching a foot or more in diameter. Some pebbles are well rounded, others flat and with the edges rounded off. They consist entirely of coarse sandstones, probably derived from the Cathedral Beds, and resemble fluviatile (valley-plain) deposits.

2. *The Basal Rhyolite.*

Locally, rhyolites of relatively small extent and thickness overlie the basal conglomerate, or rest directly on the Silurian where this is absent. These rhyolites generally show prismatic and platey jointing, and are lighter coloured and more weathered than the main flow. They are also more calcic, containing less free quartz and more plagioclase felspar (see p. 192).

3. *The Sediments.*

The basal flows of rhyolite apparently blocked the Upper Devonian streams, so that lakes were formed in which yellow and red sandstones, and red, blue and green shales were deposited. These sediments have yielded a fish fauna and remains of plants. The following forms occur:—

Ostracodermi.	*Bothriolepis gippslandiensis*, sp. nov.	
Dipnoi.	*Eoctenodus microsoma*, gen. et sp. nov.	
	Holonema cf. *rugosum* Newberry, 1889.	

This assemblage is a typically Upper Devonian one (see p. 198).

Numerous round impressions in the fossiliferous blue shales probably represent bubble impressions, the gas coming from the decomposition of the inclosed organisms (Twenhofel, 1921, 1926, p. 289). Round the organic remains, especially the plants, and along joint planes, the blue shales are buff in colour. The jointing, especially in the sandstones, is much less regular than in the Silurian beds which underlie the Upper Devonian.

East of Buxton, bedded tuffs and volcanic breccias overlie the basal rhyolite, and underlie the basalt and main rhyolite. The tuffs are of two kinds, one a blue-black, well-jointed, compact rock, grading with increased size of its component particles into the volcanic breccias, and the other a light, chocolate, poorly-jointed, fine-grained rock. Both are products of the basic igneous activity.

The volcanic breccias compare almost exactly in hand specimen and microscopically with Teale's "basal beds" from the Mt. Wellington area, labelled by him "basal breccia." In that area the relations of these beds were not clear, but at Buxton they are evidently part of the basal beds of the Upper Devonian series, as thought by Teale to be the case. Above them comes the basalt to which they are undoubtedly related.

4. *Basalt* (pp. 191).

Very dense, fine-grained, hard blue-grey basalts occur fairly constantly above the sediments and below the main rhyolite.

They are occasionally absent, as at the Sugarloaf and in the extreme north. At their farthest northerly occurrence they rest directly on the basal conglomerate, without any intervening sediments. There they are very amygdaloidal at the base, the amygdales being filled with chlorite and chalcedony, and there are small amygdales in most of the basalt sectioned from higher up in the flow. In other parts of Victoria the basalts are interbedded with the rhyolites, and always occur " consistently higher in the series than the Wellington rhyolites " (Teale, 1920). Although the name " melaphyre " has usually been applied to similar rocks by workers in other areas, the author feels that in view of their relatively fresh state, the term basalt is most suitable in the present case.

5. *Rhyolite β* (pp. 190).

In the north, a small flow of a black aphanitic rock with small, clear quartz crystals occurs above the basalt and beneath the main rhyolite. It is, again, less acid than the main flow.

6. *Rhyolite α* (pp. 188).

The most constant of the Upper Devonian rocks is the main rhyolite. Its thickness must be very great, though this was not determined, only the lower edge of the flow being examined. Its coarseness of grain led it to be identified as granite by the early surveyors.

The problem of the separation and distribution of the Upper Devonian and Lower Carboniferous series in South-Eastern Australia has long been a vexed one, and the discovery of the fish remains at Taggerty serves to give some definition to the data. Not only as regards structure and field relations, but also both macroscopically and microscopically, the rhyolites, " melaphyres," tuffs, conglomerates, shales and sandstones in the Cathedral district compare with similar rocks in the Upper Palaeozoic belt in Eastern Victoria, and the growing ideas as to their Upper Devonian age are strengthened. It should be noticed that the Taggerty fishes occur in beds stratigraphically beneath the main rhyolite flow, while many of the Lepidodendron sandstones in the great Upper Palaeozoic belt occur well above this flow, as at Mt. Wellington.

PLEISTOCENE (?) TO RECENT.

Deposits of greater age than the alluvium of the river valley-plains are represented in the alluvial fan from the Blue Hills, east of Taggerty, and the numerous alluvial cones and piedmont alluvial plain on the western slopes of the Cathedral Range. The creek which enters the Little River after flowing west past Andrews' house, aided by smaller streams, both tributaries of itself and of the Little River, has built an extensive alluvial fan. Owing to the removal of the lower edge of this by the Little

River, these streams are all now incised into the fan. It is composed of boulders, grading downwards in size to the individual quartz grains weathered from the rhyolites. The water-table is everywhere near the surface, as is shown by the numerous seepages which occur, both on its surface and more especially along its lower edge, where it is terraced by the Little River. The soil is rich. and the abundance of water and sheltered position make it valuable as farm land.

The talus produced by the rapid erosion of the Cathedral Range has formed extensive and very thick deposits between that range and the Acheron River. The numerous small wet weather streams which flow westwards down the escarpment face have each built a steep alluvial cone, and the coalescence of these has produced a very thick, continuous sheet of sediments. The streams which produced the sheet are now incised into it, because of the terracing of the lower edge by the Acheron. These deposits began to accumulate when the Cathedral Beds were exposed, in the process of dissection of the peneplain which was developed over Victoria in early Tertiary time. The date of the deformation of this peneplain is uncertain, but it is very probable that some of the above described deposits are at least as old as the Pleistocene.

The Acheron and Little Rivers and many of the smaller streams have alluvial flats, composed mainly of coarse boulders with interstitial fine silts. These flats are often swampy, especially in the upper reaches of the Little River. There, also, perfect small examples of alluvial cones are developing at the mouths of small streams from Chapel Hill. These cones have developed on top of the river alluvium since the last big flood, as they are unmodified by the river, the streams which formed them wandering indiscriminately over their surfaces.

Summary.

After the deposition of the Upper Silurian beds in shallow epicontinental seas (and perhaps other environments in part), they were compressed in Siluro-Devonian or Lower Devonian times, into a series of large folds. Probably in the Lower Devonian, associated with the final earth movements, a large sill or dyke of granodiorite was intruded in the south, and some smaller apophyses in the north. Before the Upper Devonian, normal faulting occurred. Owing to the acceleration of erosional processes consequent on the high relief imposed by the fold movements, Lower and Middle Devonian times are represented by an unconformity. Continental deposits accumulated in the Upper Devonian in lakes formed by the dislocation of the drainage system by small flows of rhyolite. In late Upper Devonian time basalts and huge masses of acid lavas were extruded. Subsequently, the region was subjected to pressure from ESE. and WNW., producing the present strikes and dips of the Silurian and Devonian rocks.

From the Upper Devonian to the Pleistocene, the resultant of earth processes has been erosion, and no deposits are found of an age intermediate between these two periods. In the early Tertiary a peneplain was produced, which later suffered uplift, so that it is now in process of dissection. Locally, continental deposits of Pleistocene and Recent age were produced, and these are even now being removed by the streams.

Petrography.

(The numbers in square brackets refer to slides in the collection at the Geology School, University of Melbourne.)

Rhyolite a. Cordierite Nevadite.

(Pl. XVII., Fig. 1.) [2244; 2245.]

Macroscopically and microscopically, this flow is extremely constant over the seven miles studied. It is a compact rock with dark cryptocrystalline groundmass and very numerous phenocrysts, a few millimetres in diameter, of clear quartz and cloudy felspar, usually white, but sometimes pink, and an occasional biotite. Fluxion structure is developed only along the lower edge, and even then is infrequent, though some beautiful specimens were found, coloured by weathering. Throughout the whole flow to some extent, but becoming more numerous towards the base, are xenoliths of sandstone and shale. Where the flow rests on the Cathedral sandstones the sandstone xenoliths are more numerous, and where it rests on the more shaly typical Silurian beds, the shale xenoliths, often altered to a spotted shale and always indurated, are more frequent. A few xenoliths of the basalt were found.

Chemical Composition.

	1.	2.	3.
SiO_2	74·72	74·39	78·64
Al_2O_3	13·05	14·28	9·85
Fe_2O_3	0·52	0·52	0·54
FeO	1·42	1·09	2·00
MgO	0·41	0·27	0·10
CaO	0·66	0·24	0·80
Na_2O	3·62	2·78	2·03
K_2O	4·31	5·33	5·16
H_2O+ . . .	0·61	0·22	0·40
H_2O- . . .	0·13	0·56	0·14
CO_2	0·08	—	—
TiO_2	0·16	0·29	0·67
P_2O_5	0·38	tr.	tr.
MnO	—	n. det.	—
F	n. det.	n. det.	n. det.
Cl	tr.	n. det.	n. det.
Total	100·07	99·97	100·33

1. Rhyolite, Blue Hills, Taggerty. Analyst, E. S. Hills.
2. Rhyolite, Archer's Lookout, Narbethong, Analyst, N. R. Junner.
3. Rhyolite, Mount Wellington. Analyst, E. O. Thiele.

Norms and Classification.

	1.	2.	3.
Quartz	35·58	36·30	44·52
Orthoclase	25·58	31·69	30·58
Albite	30·39	23·63	17·29
Anorthite	0·56	1·11	2·22
Corundum	2·24	3·47	—
Hypersthene	2·85	1·76	2·68
Magnetite	0·70	0·70	0·70
Ilmenite	0·30	0·61	1·22
Apatite	0·93	—	—
Class—	Persalane	Persalane	Persalane
Order—	Quarfelic	Quarfelic	Quarfelic
Rang—	Peralkalic	Peralkalic	Domalkalic
Sub-Rang—	Sodipotassic	Sodipotassic	Do-sodipotassic
Magmatic Name—	Alaskose	Alaskose	Mihal-Tehamose

Under the microscope the quartz phenocrysts are seen to be rounded and embayed, often very deeply. The felspar is microperthitic orthoclase, the included felspar being quite abundant. It has a greater refractive index and double refraction than the orthoclase, and shows polysynthetic twinning. The high soda (and low lime) content of the rock points to the perthitic intergrowth as being albite or oligoclase-albite. The orthoclase phenocrysts are nearly as numerous as those of quartz, and about the same size; they show some rounding of the corners and edges, and are very fresh. Small plagioclase phenocrysts are of infrequent occurrence. Though the maximum extinction on the albite twinning lamellae ranges up to 26° in these, the refractive index is less than that of quartz. They may be oligoclase-andesine. A small amount of biotite is present in all sections, while in one it is more abundant as small flakes in a rather coarser groundmass than usual. Colourless cordierite, fresh in part, but often altered to muscovite (pinite) or almost isotropic chlorite, is also present. One section exhibits a trilling, but often all that remains of the original mineral is a brown micaceous or chloritic mass. Small blue tourmalines occur as single crystals and as radiating aggregates, and are often associated with the material filling the embayments in the quartz crystals. Small black specks in the groundmass are probably ilmenite.

The groundmass is micro- to cryptocrystalline, and always shows well-developed flow structure, the contorted lines curving round the phenocrysts of quartz and felspar, which are not arranged linearly. Biotite crystals curve with the flow lines, and

wrap round the quartz and felspar. On solidification, the groundmass was evidently a glass, varying in composition from point to point. Some bands are coarser than others, and consist of colourless mica and material with undulose extinction and fairly high double refraction, which is probably a soda felspar. Other bands are cryptocrystalline, much of the material having a higher refractive index than quartz. Again, in some cases biotite flakes, quartz, felspar and colourless mica can be recognised, and occasional microspherulitic aggregates occur. Apatite needles are seen in the quartz and orthoclase, but the high norm of this mineral indicates that some is present in the groundmass.

Junner (1914) has described rhyolites from near Narbethong, which resemble very closely the above rock. He mentions, among other things, the occurrence of blue tourmaline, corroded quartz, and perthitic orthoclase. The analyses show an evident similarity also.

Rhyolite β [2246].

This is a black aphanite with small, clear quartz crystals and turbid felspar. Under the microscope it is seen to be crowded with angular fragments of quartz and felspar, which appear to represent broken crystals. This might be due to continuation of the process of embayment till the crystals are eaten through, or (Rosenbusch; Osann, 1923) to rapid cooling of the rock giving rise to shattering of the crystals. The felspar is both plagioclase and orthoclase, the former giving a maximum paired extinction of 22° on the albite lamellae, having a lower double refraction than that of quartz, and a high refractive index. It is thus andesine. Carlsbad twinning is sometimes shown as well as the albite, and zoning is well developed. The orthoclase is in general untwinned, and is about equal in amount to the plagioclase. A few fragments of pink garnet, and biotite flakes are present. The groundmass is cryptocrystalline, and micro-fluxion structure, due to an originally heterogeneous magma liquid, is sometimes seen. Apatite, inclosed in quartz crystals, is a common accessory, and veinlets of epidote and zoisite traverse the rock. A somewhat clastic appearance is shown under the microscope, and cherty-looking aphanites from near Narbethong have been described as silicified tuffs by Junner (1914). However, in the present case, the evidence points rather to solidification with sudden chilling of a lava flow, perhaps under water. Thus,

(*a*) Some of the shattered phenocrysts have not been separated, and the fragments as seen may be imagined as fitting together.

(*b*) The micro-fluxion structure shows that the groundmass is not clastic but igneous, representing a devitrified glass.

(*c*) The rock does not contain lapilli, and is quite distinct from the pyroclastics which occur at Buxton.

(d) The epidote and zoisite veinlets may be due to the action of caught up and heated water on the groundmass of the rock.

Small (microscopic) xenoliths of sandstone and basalt occur, but are not large enough to be seen in hand specimen.

An analysis of the rock gave the following result:—

		Norms and Classification.	
SiO_2	70·81	Quartz	33·48
Al_2O_3	15·73	Orthoclase	32·25
Fe_2O_3	0·76	Albite	14·67
FeO	1·97	Anorthite	6·95
MgO	1·30	Corundum	4·39
CaO	1·68	Hypersthene	6·47
Na_2O	1·75	Magnetite	0·70
K_2O	5·44	Ilmenite	0·15
H_2O+	0·54	Apatite	0·47
H_2O-	0·10	Class—Persalane	
CO_2	—	Order—Quarfelic: Columbare	
TiO_2	0·09	Rang—Domalkalic: Alsbachase	
P_2O_5	0·22	Sub-rang—Dopotassic: Mihalose	
Total	100·09	Analyst—E. S. Hills.	

Basalt [2250].

This is a hard, dense, fine-grained, grey rock. Under the microscope small phenocrysts of pale green augite are common, and these are sometimes glomeroporphyritic. Labradorite also occurs as phenocrysts and felted laths in the groundmass. Small rectangular crystals of black iron oxide are numerous, and carbonates are present in the groundmass. Irregularly shaped vesicles are scattered throughout, and contain mainly chalcedony, though in some concentric bands of chlorite are seen.

The rock is moderately fresh, but some chloritization of the pyroxenes has gone on, and an occasional large felspar shows complete decomposition to colourless mica, though others are quite unaltered. Local variations are mainly textural, one section showing macroscopic crystals of iron oxide, but no plagioclase or augite phenocrysts. In the north the flow is amygdaloidal, the amygdales being about a quarter of inch in diameter, and very numerous. They are filled with chalcedony and chlorite.

Volcanic breccia [2248].

This rock is dense, and contains numerous lapilli of grey-black altered basalt, set in a lighter-coloured matrix. The lapilli do not exceed an inch in length, and they grade downwards to small grains in the tuffs. Under the microscope the lapilli are seen to be of porous altered basalt, the vesicles being filled with chlorite and chalcedony, also epidote and carbonates. Numerous rhomb-shaped sections of an altered mineral occur, composed of serpentine and showing irregular cracks along which iron oxide is segre-

gated. These are almost certainly altered olivine, and they are present in both the lapilli and the groundmass, in the latter case as fragments bounded by the curved fracture lines. The absence of olivine in the basalts above the tuffs is interesting, and indicates that the augite was produced by the reaction of the olivine with the magma. Small iron oxide crystals are numerous. In the groundmass of the rock detrital quartz occurs, with fragments of altered olivine and small fragments of the basalts.

Basalt tuffs.

The finer grained pyroclastics have weathered very strongly, giving chocolate and purple soft, light and friable material. The breccias and tuffs are both well bedded and jointed.

Basal rhyolite [2247].

The flows at the base of the series are less acid than the main rhyolite. They are light or dark grey, with a few quartz crystals and abundant tabular felspars set linearly in a fine-grained groundmass. Under the microscope, altered felspar and biotite and embayed quartz phenocrysts are seen. Acid oligoclase apparently predominates over orthoclase, though the alteration makes determination uncertain. Numerous blebs of limonite are apparently pseudomorphous after magnetite, the original parallel growth of the cubic crystals being readily made out. The groundmass is microcrystalline to cryptocrystalline.

Granodiorite-porphyrite [2249].

In hand specimen this rock shows moderate sized phenocrysts of quartz, white felspar and biotite, set in a finer groundmass. Much fissured pink garnets occur sporadically. They show dodecahedral outlines and are about half an inch in diameter. A few biotite-rich " basic segregations " were seen, and some xenoliths of country rock, altered to hornfels.

Under the microscope, the quartz is seen to be embayed. The rock weathers readily, all the specimens examined having cloudy felspars. The plagioclase gives a maximum extinction of 20° on the albite twin lamellae, and is andesine. Orthoclase is subordinate in amount to the plagioclase. The biotite is bleached and chloritized, and has numerous inclusions of zircon as elongated crystals arranged along the cleavage planes. Some zircon and apatite occur in the groundmass, which is composed of quartz, biotite and felspar. The latter is in part twinned plagioclase of lower refractive index than that of quartz, probably oligoclase, and in part untwinned felspar of low double refraction and lower refractive index than that of quartz, probably orthoclase. The cracks in the garnets are filled with chlorite and inclusions of biotite and apatite are present.

The Buxton and Taggerty granodiorites are exactly similar both macroscopically and microscopically, except that in a slide of the latter a fairly large piece of blue tourmaline showing radiate structure occurs.

Palaeontography.

FISH AND PLANT REMAINS FROM TAGGERTY.

Plantae.

The fragmental plant remains found in the blue shales which yielded the fishes described below are incapable of exact definition. Some are narrow, alternately branching stems, with indications of a relatively large central woody (?) cylinder. Miss I. Cookson, who examined these remains in the hope that they might be Psilophytales, says that they yield no indication of structure on treatment with hydrofluoric acid, and are indeterminate.

Others are unbranched and show indications of longitudinal ribbing, both coarse and fine. These resemble the "*Cordaites*" *australis* McCoy, from the Avon River beds.

Class PISCES.

Sub-class DIPNOI.

Order CTENODIPTERINI.

Family CTENODONTIDAE.

Eoctenodus, gen. nov.

EOCTENODUS MICROSOMA, gen. et sp. nov.

(Plate XVIII., Figs. 2-7; Text-fig. 2, Nos. 1, 2, 3, 5, 6.)

Type Material.—Dentaries of mature and immature individuals. Parasphenoid and median occipital bones of mature individual. Scales. Bones of the shoulder girdle.

The Palate.—Specimen JA. Impression of the lower surface of the left dentary (pterygopalatine with attached dental plate), preserved in fine blue shale, and cleaned by weathering. Dental plate elliptical, 0·55 cm. wide and 1·50 cm. long, bearing 10 denticulate sub-parallel ridges. The ridges increase in size from 1 to 10 (see Text-fig. 2, No. 1), and the denticles increase in size from inside to outside, being directed apically outwards.

Pterygopalatine. Maximum length 1·85 cm., maximum width 0·90 cm. (Text-fig. 2, No. 1, and Pl. XVIII., Fig. 7). JA shows the usual transverse crack across the alate extremity, but even so a distinct downward turn of this part is noticeable. No scar is present on the inner edge such as has been described for *Sagenodus* and *Ctenodus* (Watson and Gill, 1922-24), due to overlap of the parasphenoid. In *Eoctenodus* the latter bone apparently abutted against a ridge on the pterygopalatine. As is usual, the

symphysis of the left and right pterygopalatines was weak, the three specimens found being separate. Both extremities of the alate portion are rounded and the lateral edges smoothly curved.

Specimens JE 3, JB 1. Mould of the left dentary, preserved in the same blue shale as JA, but unweathered. General description as for JA, but 9 ridges only present on the dental plate, and the whole somewhat smaller in size, indicating a younger individual. Differs also in that the ratio of breadth to length is greater than in JA. Pterygopalatine unbroken, and showing marked downward curving of the extremity. Thickness of dental plate at outer edge 1·25 mm.

Specimens C. XVII., *a,b*. Mould of left dentary of a very small form, probably the young of *Eoctenodus*. The dental plate measures only 0·4 cm. by 0·2 cm., and bears eight ridges, strongly denticulate, and all slightly concave forwards. Pterygopalatine relatively large compared with the dental plate, and of a peculiar shape (see Pl. XVIII., Fig. 2). Four denticles present on the larger ridges, directed apically outwards.

Specimens JFA, JF. Mould, in the same matrix, of a parasphenoid, the posterior shaft being incomplete. Length 3·5 cm., width 1·4 cm. JFA shows the impression of the cranial (dorsal) surface, and a plasticine squeeze reveals a ridge round the anterior part of the lozenge, which may have abutted against a similar ridge (*vide ante*) on the buccal surface of the pterygoids. Posteriorly a central ridge extends from the centre of the main lozenge into the attenuated basisphenoid. A peculiar median pit is situated on the anterior part of the lozenge. (Pl. XVIII., Fig. 5; Text-fig. 2, No. 5).

Cranial Roof Bones.—Specimens C.MO 1, 2. Mould, in the same matrix, of a median occipital, incomplete. Anterior process relatively large and sharply defined. Estimated length (of median occipital) twice the breadth. One surface smooth (outer ? surface), and bearing only slightly developed radiating ridges, the other, of which only the anterior part is preserved, bearing finely sculptured lines, radiating from the centre of the bone. Maximum thickness, 1·5 mm. Length of anterior process 8 mm., breadth of bone about 2·0 cm.

Specimen JD. Impression, in the same matrix, of a circumorbital (?) bone. 7·8 mm. by 4 mm., 1 mm. thick. It shows ridges radiating from a central rosette, and is bevelled along the two long edges, the surfaces of the bevel being roughened.

The Shoulder Girdle.—The Clavicle. Specimen C.C. Mould, in the same matrix, of the upper surface of the right clavicle. Shaft long and narrow, 2·4 cm. long, 0·6 cm. wide, tapering at the articulating end, which bears a well developed ridge and hollow. Head imperfectly preserved, but apparently not very long. The end of the shaft is cracked across and slightly displaced, and this may indicate that it has been flattened from a twisted shape.

The Cleithrum. Specimens C XVIII. *a,b.* Mould, in the same matrix, of the left cleithrum. Outer surface with a very strong, central ridge, continued into a strong articulating process. Outer edge thickened. The bone is concave inwardly (the orientation being as given by Watson and Gill, 1922-24), but has been crushed in preservation due to collapse of the thick, spongy, bony structure, so that it is probably incomplete at the expanded end. (Pl. XVIII., Fig. 4; Text-fig. 2, No. 6.)

Bones, indet.—C XV. 1. Group of small cylindrical bones, associated with a longer linear group. These may be fin-bones.

2. Fine straight bones up to 1 inch long. These may be ribs or fin rays.

C.C. Strong, curved bone with expanded end, oval in section. This may be a neural spine.

Squamation.—Scales thin, often subquadrate with rounded corners and slightly concave edges. Internal structure of fine radiating ridges and furrows. Exterior smooth, marked by concentric growth lines, the centre of growth being excentric. The largest found measured 14·25 mm. by 12·75 mm. A few subrhomboidal scales were found, and these are smaller. Some show what is thought to be remnants of the lateral line (Pl. XVIII., Fig. 3.)

Relationships.—The dipnoan above described shows relationships with *Ctenodus* in some of the characters of the dental plate, with its sub-parallel ridges and elliptical shape, the well defined anterior process of the median occipital, the relatively large, thin, sub-quadrate scales and the bones of the shoulder girdle. It is related most closely to the small or moderate sized *C. interruptus* of the Lower Carboniferous, but is distinctive in the fewer ridges on the dental plate, and is separated from all forms of *Ctenodus* by its distinctive parasphenoid, which indeed serves to separate it from all other dipnoans. In size it probably approximated to that of *Phaneropleuron* and *Scaumenacia.*

Subclass OSTRACODERMI.

Order ANTIARCHA.

Family ASTEROLEPIDAE.

Bothriolepis Eichwald, 1840.

BOTHRIOLEPIS GIPPSLANDIENSIS, sp. nov.

(Plate XVIII., Fig. 8; Text-fig. 2, No. 4.)

Type Material.—Impression of some plates of the head; impression of the external marginal of the right appendage.

Plates of the Head.—Specimen C.B. Impression, in fine, irregularly fracturing sandstone of the dorsal surface of some of the head plates of a *Bothriolepis.* Surface ornamentation of tubercles, fused more or less at their bases, producing distinctly

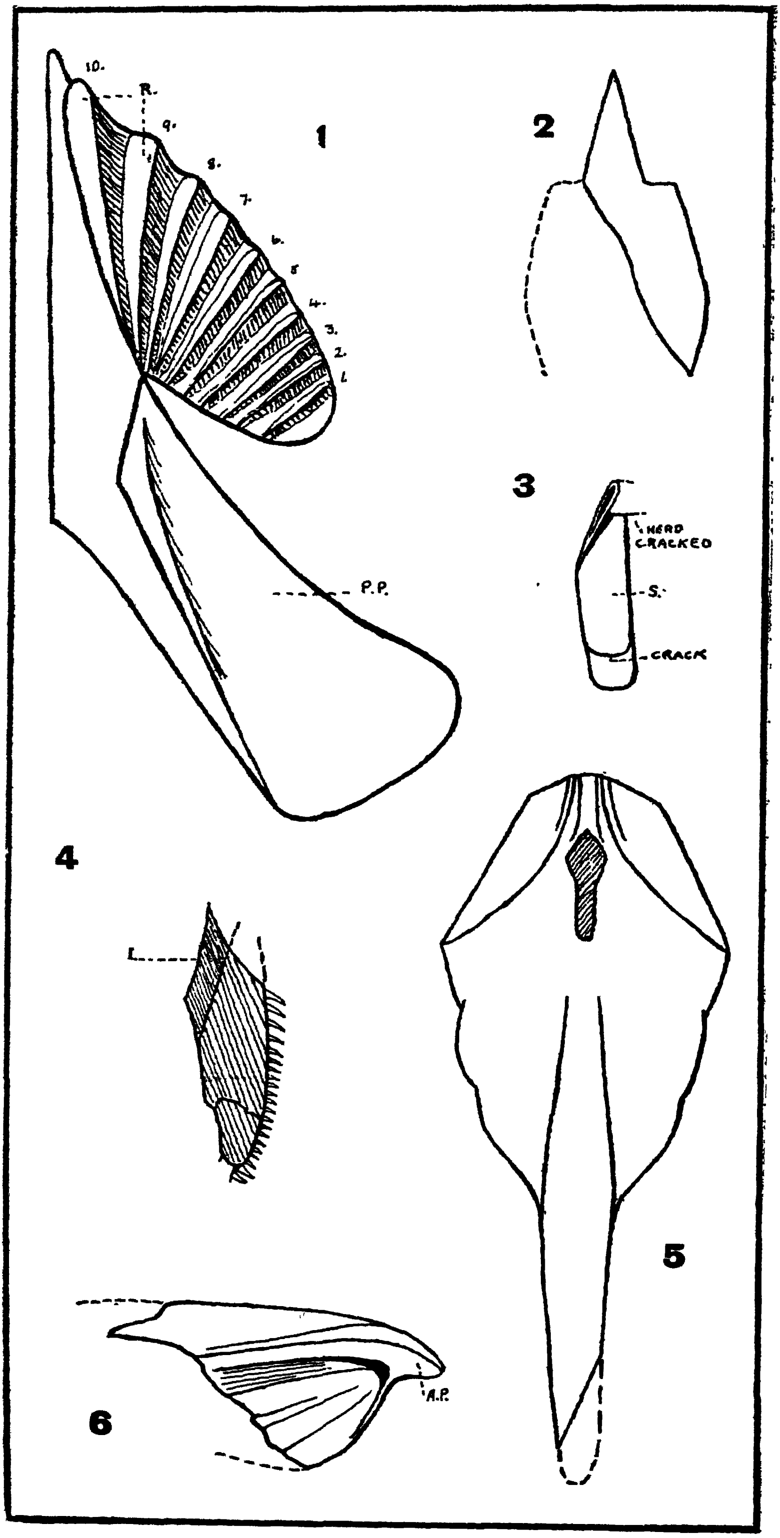

FIG. 2.

nodose ridges. The tubercles are often arranged linearly, e.g., parallel to the sensory grooves, which are united by a V-shaped commissure behind the orbits, and appear to bend round at the sides of the latter, instead of further anteriorly as in *B. canadensis* and *B. hydrophila.* (Pl. XVIII., Fig. 8.) Fracturing and displacement of the plates during preservation has, however, rendered the paths of these grooves outside the median occipital uncertain. The latter is wider than long, width 1·8 cm., length 0·9 cm. The post-median is missing, as are the orbitals.

Lateral Appendages.—Specimen C.L. Impression, in the same fine sandstone, of the external marginal plate of the right appendage. Marginal denticulations very strong. Ornament of fine parallel ridges, parallel to the line of junction with the interior marginal plate, and hence making an acute angle with the denticulate margin. Maximum width, 0·75 cm., exclusive of the denticles, length along the junction with the interior marginal 1·7 cm. The sudden constriction distally indicates that the distal end of the appendage is narrower than the proximal (Fig. 2, No. 6).

Relationships.—The above *Bothriolepis* resembles *B. canadensis* in the strongly denticulate margins of the appendages, but differs in the relatively short, compressed median occipital, in the disposition of the sensory grooves, and in size.

Sub-Class DIPNOI.

Order ARTHRODIRA.

Family PHYLLOLEPIDAE.

Holonema Newberry, 1889.

HOLONEMA cf. RUGOSUM Newberry, 1889.

Specimen C.H. Mould, in fine sandstone, of a plate of a placoderm fish, incomplete. Specimen measures 5 cm. by 2·5 cm. Ornament of radiating rugae, which are rounded, and in general equal in width to the separating grooves. One edge shows a slightly obtuse angulation. Maximum thickness shown 2 mm., which is near an edge, so that probably the plate was thicker in other parts. Compares almost exactly in pattern and size with the figure given by Newberry (1889, pl. xviii., fig. 4). "*Holonema rugosum.* Portion of lateral plate of carapace(?), natural size."

FIG. 2.

1. *Eoctenodus microsoma*, sp. nov. Dentary, drawn from a wax squeeze. R., Denticulate ridges (denticulations not shown), numbered from 1 to 10. P.P., pterygopalatine. ×4.
2. *Eoctenodus microsoma.* Median occipital, in part restored, showing anterior process. ×2.
3. *Eoctenodus microsoma.* Clavicle, drawn from a wax squeeze. S, shaft. ×1.
4. *Bothriolepis gippslandiensis*, sp. nov. External marginal of the right appendage. I, inserted area. ×4/3.
5. *Eoctenodus microsoma.* Parasphenoid restored. Cranial surface, from a squeeze. The shaded area is a pit. ×13/5.
6. *Eoctenodus microsoma.* The cleithrum, from a wax squeeze. A.P., articulating process. ×3/2.

Discussion.

The assemblage of fishes above described is a typically Upper Devonian one, and resembles in a remarkable way the suite of Chemung (Upper Devonian) age at Scaumenac Bay, Canada. In both localities we find a primitive small dipnoan, a coccostean form, and *Bothriolepis,* associated with plant remains (and in Canada, more fishes). This is interesting in view of the close resemblance Benson has shown to exist between the marine Upper Devonian rocks of New South Wales and the Chemung marine beds of the Eastern United States (Benson, 1922).

It is interesting to note that Dr. Smith Woodward writes (1904): "It may be said that ... *Bothriolepis* and *Asterolepis* characterise the Upper Old Red Sandstone or Upper Devonian wherever it occurs—in Britain, Belgium, Germany, Russia, Spitzbergen, Greenland, Canada and the Catskills of New York." As the only other Upper Devonian fossils which had been found in Victoria up to the present were plant remains, some of which are of doubtful value, the present discovery serves to give some definition to our ideas of the Upper Palaeozoic succession in Victoria.

In conclusion, I wish to acknowledge my indebtedness to those who have freely given their advice and help during the progress of the research. To Professor Skeats especially, under whose direction the work was carried out, I must convey my thanks for his ready counsel on all occasions, his companionship for a few days in the field, and his criticism and encouragement. To Mr. Chapman, who has been my guide on all palaeontological questions, who determined some of the Silurian fossils, and who allowed me to use specimens in his care at the National Museum for comparison; to Miss I. Cookson, for help with the plant remains; to Mr. D. McCance, who smoothed out my paths in chemical analysis; and to Mr. J. S. Mann, who photographed the specimens figured in this paper, I must also express my thanks.

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EXPLANATION OF PLATES.

PLATE XVII.

Geological Map of the Cathedral District.

Notes on the Map.

The absence of contours renders the interpretation of this map a little difficult, because of the strong relief. The bending round of the outcrops of the Cathedral Beds at the north and south ends of the range is due to the form assumed by the beds on erosion. Between Chapel Hill and the Cathedral Range there is probably a fault, whose line is hidden under alluvium.

The wave-like edge of the talus along the Cathedral Range is meant to represent the numerous regularly developed alluvial cones descending from the escarpment.

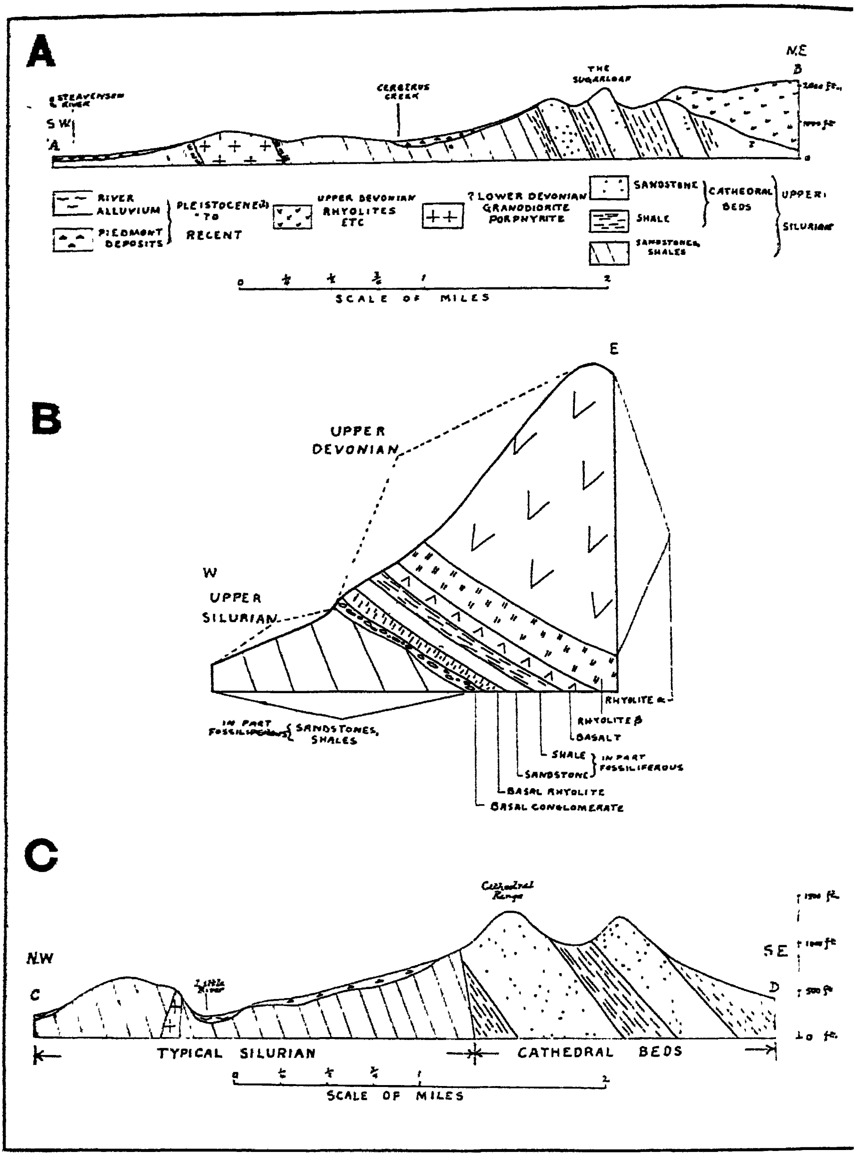
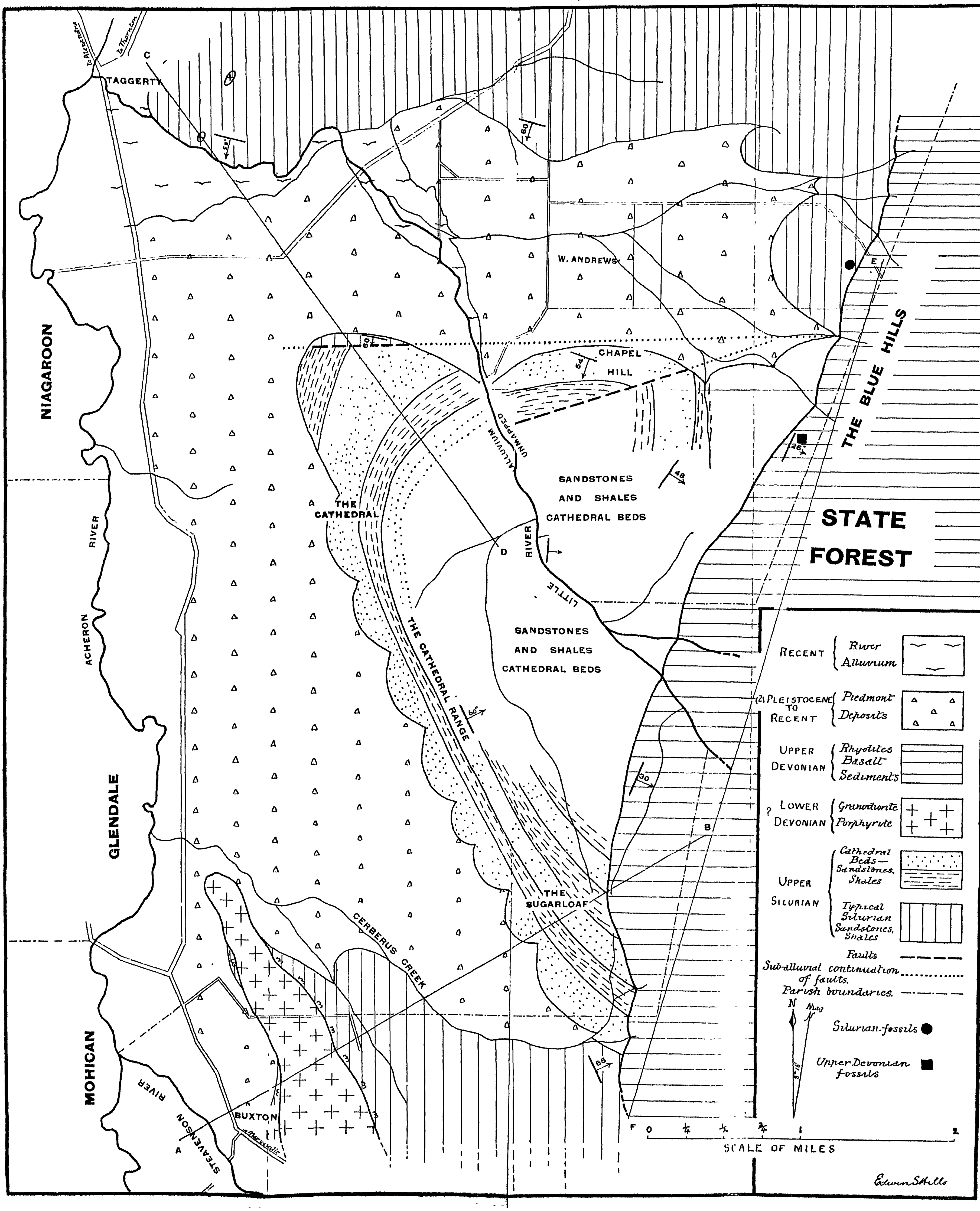


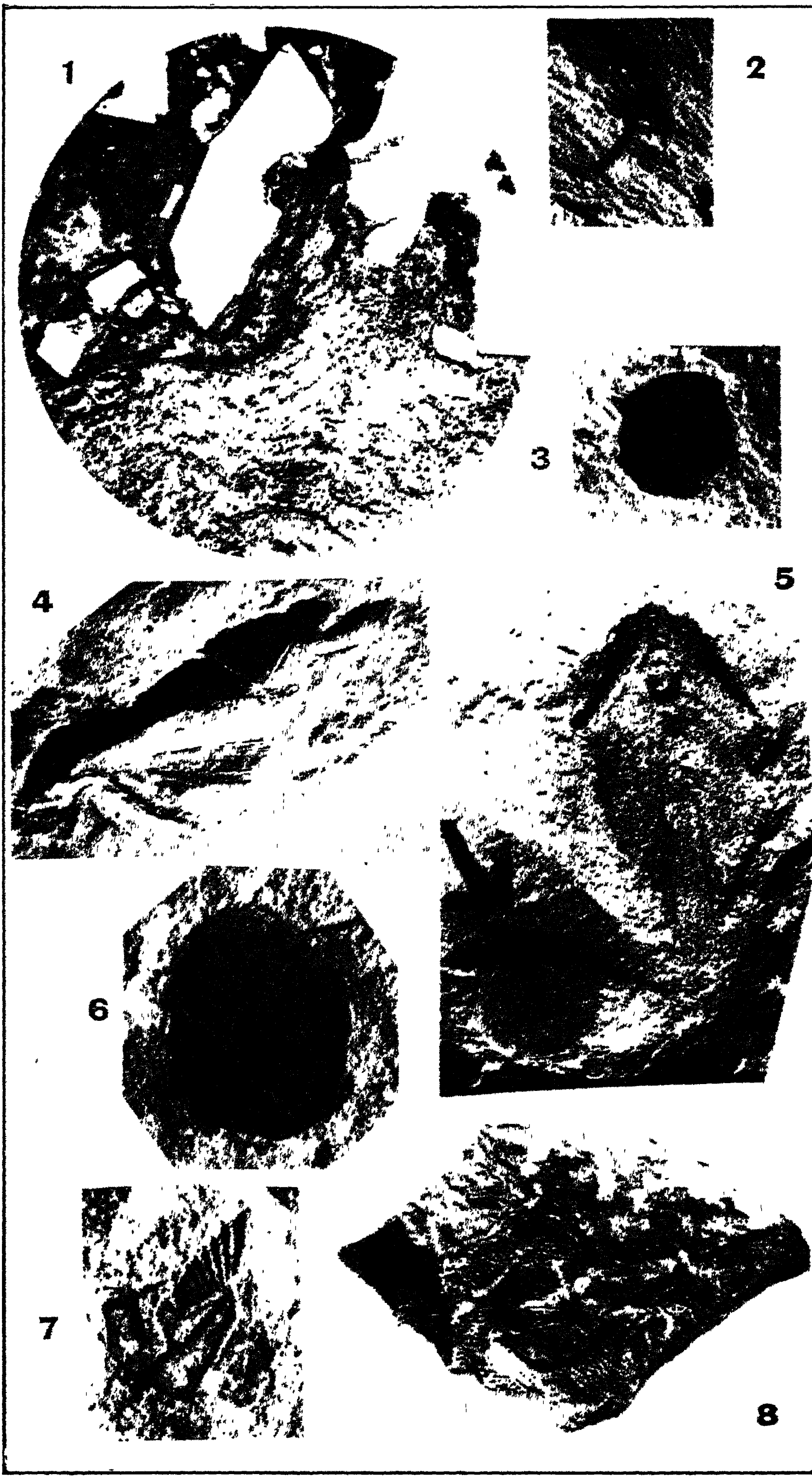
FIG. 3.—A: Sketch section along the line A B from SW. to NE. through the Sugarloaf, Buxton.

B: Diagrammatic section from west to east across the summit of the Blue Hills, showing the relations of the Upper Devonian and Silurian rocks in the north.

C: Sketch section along the line C D from NW. to SE., across the north end of the Cathedral Range, Taggerty.

GEOLOGICAL MAP OF THE CATHEDRAL DISTRICT





Devonian Fishes, Taggerty.

PLATE XVIII.

Fig. 1.—Section of Rhyolite α (cordierite nevadite), from the Blue Ranges, Taggerty. Ordinary light, showing embayment of quartz, and flow-structure in the groundmass. × 25.

Fig. 2.—*Eoctenodus microsoma*, sp. nov. Impression of buccal surface of left dentary of young. ×2. [770].

Fig. 3.—*Eoctenodus microsoma.* Scale, showing lateral line. ×2. [771].

Fig. 4.—*Eoctenodus microsoma.* Impression of the outer surface of the left cleithrum. ×5/3. [772].

Fig. 5.—*Eoctenodus microsoma.* Impression of the cranial surface of the parasphenoid, incomplete posteriorly. ×2. [773].

Fig. 6.—*Eoctenodus microsoma.* Scale, showing internal structure. ×2. [774].

Fig. 7.—*Eoctenodus microsoma.* Impression of buccal surface of the left dentary, and another small bone, indet. ×1. [775].

Fig. 8.—*Bothriolepis gippslandiensis*, sp. nov. Impression of the exterior surface of part of the head, showing median occipital bone with V-shaped sensory canals. ×1. [776].

Note.—Owing to an optical illusion, it is possible that the impressions of the bones of *Eoctenodus* (Figs. 2, 4, 5, and 7) may appear as the actual or positive, rather than the impression.

Numbers in brackets refer to registered specimens in the collection of the Department of Geology, University of Melbourne.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. XIII.—*On the Flanged Cowry, Palliocypraea gastroplax.*

By FREDK. CHAPMAN, A.L.S., F.G.S., etc.

(With Plates XIX., XX.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

Occurrence of Specimen.

The remarkable cowry described by the late Professor Sir Frederick McCoy, under the name of *Cypraea gastroplax* (McCoy, 1875, p. 20, pl. xvi., fig. 1; pl. xvii.; pl. xviii., fig. 2), remained a unique specimen, so far as the National Museum collection is concerned, until the subject of this note was found by Mr. Walter Greed, of Hamilton. Mr. Greed discovered his specimen, a nearly perfect example, in the lower beds at Clifton Bank, Muddy Creek, Hamilton. He presented it to the National Museum on the 3rd March, 1924 (Reg. No. 13273). The fragility of the Muddy Creek specimen makes it surprising that the shell was obtained in so perfect a condition. As it is, however, a portion of the thin shelly flange has developed cracks more or less parallel with the periphery, and portions that came away had to be supported with paper. Other fractures seen in the shell run in zig-zag fashion across these peripheral cracks right through the flange into the dome of the shell. The prevalence of these fractures in the shell and flange seems to suggest that there was an abnormal amount of organic basis in this type of shell, which, on the extraction of the specimen from the stratum gave rise, by rapid drying, to contraction and compensatory rifting.

Detailed Description of Fossil.

The form of the body of the shell is broadly pyriform, roundly contoured anteriorly, and tapering rapidly posteriorly. The profile shows a strong humping of the body of the anterior, with the spire nearly flush with the general shape, comparable with the roundly based *Cypraea sphaerodoma* Tate. The lower surface of the shell is nearly flat, with a gently furrowed or depressed margin on the upper surface, indicating the junction of the body of the shell with the explanate flange. The aperture runs the whole length of the shell, is gently sinuous in the middle, strongly arched towards the anterior, and slightly undulose posteriorly. The usually crenate margin of the aperture is well marked, the teeth becoming obsolete at about one-fifth from either end. Both apertural openings are slightly expanded and tubular. During the

examination of this fragile specimen a portion of the flange, with the surface of the body of the shell, became loose, thus revealing a stouter shell layer beneath, over which the thin enamel lay like a glaze.

The length of the shell, from the anterior edge of the flange to the posterior, measured along the apertural region, is 97 mm. The greatest width from side to side is 90 mm. The length of the body whorl, from the centre of the spire at the apex to the base of the body within the siphonal extension, is 56 mm. The greatest width of the body whorl is 52 mm. The greatest height of the shell, measured from the base, is 33 mm.

Cossmann and Vredenburg on Palliocypraea.

Cossmann, in his original descriptions of his subgenus *Palliocypraea*, makes reference to Dr. G. B. Pritchard's specimen from Mornington, which he figures (Cossmann, 1906, pl. ix., figs. 10, 11), as the genotype of "*Rhynchocypraea* (*Palliocypraea*) *gastroplax* McCoy." Pritchard's specimen is really a plesiotype, for the genotype (which can be a name only) is *Cypraea gastroplax* McCoy. This latter is represented by the holotype of the species, in the National Museum (Reg. No. 12140). Cossmann states the age of the Mornington specimens as "Eocene," but both the Mornington and Muddy Creek (Lower) beds are now usually regarded as Oligocene, and certainly not Eocene.

In an exhaustive summary of the Family Cypraeidae, E. Vredenburg (Vredenburg, 1920, pp. 126, 128), refers McCoy's *Cypraea gastroplax* to a section of *Gisortia* under Cossmann's name of *Palliocypraea*. He cites two species—*C. gastroplax* McCoy and *C. mulderi* Tate. From a consideration of the form of the latter shell, however, it appears quite incompatible to associate the two species, for *C. mulderi* has a broadly ovoid contour to the body whorl, and the only approach to a flange is in the depressed and round edged base of the shell.

Morphological Considerations.

In his original description of this cowry McCoy said: "The enormously extended circular thin flange into which the base is extended, renders this cowry totally unlike any previously known living or fossil species." This statement still seems to hold good, and the genus *Palliocypraea* is therefore monotypic. One calls to mind the families of the *Aporrhaidae* and the *Strombidae* in which the outer lip of the body whorl is extended, flattened and fingered, and which extension sometimes involves the entire length of the shell. This extension does not, however, surround the shell, and possibly only in *Cypraea* could this be effected, since in that genus or its allies there is a greatly expanded mantle which covers, or nearly so, the whole body and base of the shell.

In *Trivia* the edges of the mantle do not quite junction, as may be seen in the median dorsal furrow dividing the costate ornament.

The flange in this species has no morphological connection with an expanded lip, as in the genera mentioned, nor with the thin everted lip of an embryo cowry, which in after life becomes introverted and crenulate. The shelly flange is, therefore, an exogenous growth in continuity with the periphery of the shell and was probably the result of using up a redundancy of shell material as a secretion of the basal part of the mantle, which otherwise would have been utilised in adding to the body whorl of this extraordinarily thin cowry shell. The shell flange, moreover, would obviously be advantageous to the cowry in creeping over an even-surfaced oozy sea-bed.

Although we consider it better to regard *Palliocypraca* as worthy of separate generic rank, there is no doubt that the body form shows it to be related to the group often referred to as *Gisortia*. Thus we may cite *C. leptorhyncha, C. ampullacea, C. eximia* and *C. sphaerodoma* as representative of this type of shell, which, indeed, was already established in Lower and Middle Tertiary times, whilst in *C. umbilicata* we have a survival to the present in Austral seas.

Conditions of Deposition in the Muddy Creek and Balcombe Bay Beds.

The bed at Clifton Bank, where Mr. Greed's discovery of *Palliocypraca gastroplax* was made, is a yellowish, friable shelly sand or marl containing numerous polyzoa and the pteropod, *Vaginella*, together with some foraminifera. The finer muddy portion of the matrix seen in the Balcombe Bay specimen is wanting in the Muddy Creek deposit, but in both localities fairly deep water conditions are indicated by the occurrence of pteropod shells.

The foraminifera of the Balcombe Bay impure limestone add somewhat to the depth estimation of water in that locality in Balcombian times, and this is further substantiated by the prevalence of glauconite grains.

At a rough estimate *Palliocypraea* lived in the Balcombian sea in the Port Phillip area at between 200 and 400 fathoms, whilst in the Muddy Creek (Clifton Bank area) its probable depth would be 100 fathoms or less.

Comparison of the Present Specimen with the Balcombe Bay Holotype.

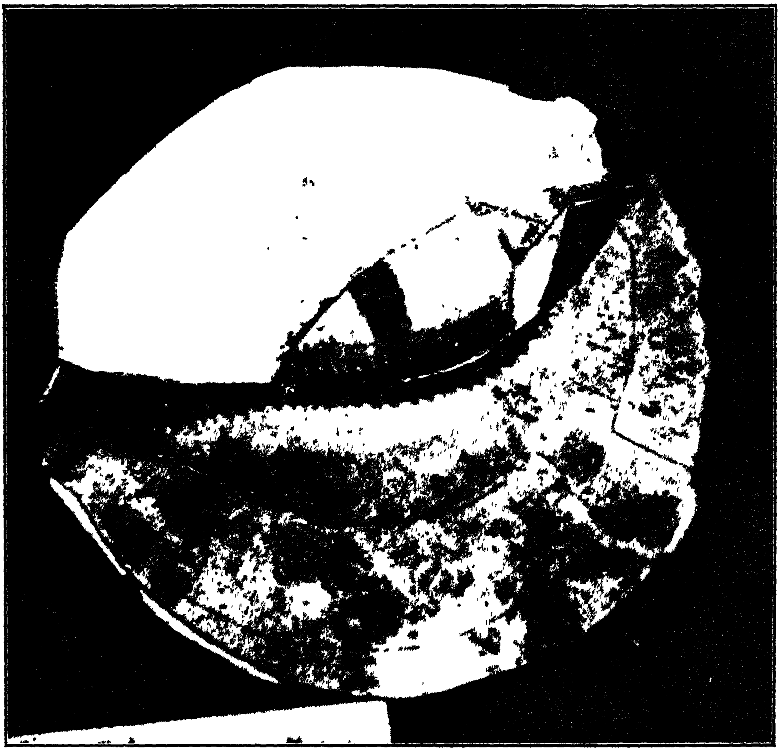
McCoy's type specimen is stated to come from "the Oligocene Tertiary limestone of the tract between Mount Eliza and Mount Martha on the shores of Hobson's Bay." In explanation we may remark that the precise locality, seeing that the shell occurred in a

FIG. 1.

F C. photo.

FIG. 2.

Palliocypraea gastroplax.



F. C. photo.

Fig. 3.

Palliocydraea gastroplax.

septarian block, is the old Cement Works at Balcombe Bay. The locality cited by McCoy as "Hobson's Bay" is probably a misprint for Balcombe Bay or Port Phillip Bay.

The type specimen (holotype) in the National Museum (Reg. No. 12140) is undoubtedly conspecific with the beautifully preserved Muddy Creek specimen. The latter is only slightly smaller in proportion, the difference in the length of the body being about 8 mm.

The type specimen is preserved in a hardened concretionary and impure limestone, the matrix of which is foraminiferal, and besides this, contains innumerable shells of the little pelagic pteropod, *Vaginella eligmostoma* Tate. The interior of the shell has been naturally filled with this *Vaginella*-bearing mud, and where the shell of the cowry has peeled away, the glass-polished surface of the mud-cast is revealed. In this condition, of a partially-fractured shell reposing on its cast, the tenuity of this species is remarkably well brought out, showing an inner, prismatic layer and the outer, enamelled shell. The inner layer is seen on a weathered surface to show that the prismatic structure radiates across the flange, whilst the enamel layer of the flange itself has a fibrous structure concentric with the periphery.

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EXPLANATION OF PLATES.

Plate XIX.

Fig. 1.—*Palliocypraea gastroplax* (McCoy). Aspect showing profile of body whorl. Circ. nat. size.

Fig. 2.—*P. gastroplax* (McCoy). Another view of dorsum. Circ. nat. size.

Plate XX.

Fig. 3.—*Palliocypraea gastroplax* (McCoy). Ventral aspect, Slightly enlarged.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART XIV.—*On some Trilobites and Brachiopods from the Mount Isa District, N.W. Queensland.*

By FREDK. CHAPMAN. A.L.S., F.G.S.

(Commonwealth Palaeontologist, National Museum, Melbourne.)

(With Plates XXI., XXII.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

The following are descriptions of a small but very interesting series of Cambrian Trilobites and Brachiopods, collected by Messrs. Campbell Miles and E. C. Saint-Smith, from the head of the Templeton River, twelve miles west of Mount Isa, and from Thornton River, NW. Queensland. These fossils were submitted to me for examination through the courtesy of Mr. B. Dunstan, F.G.S., Government Geologist of Queensland. Included in these descriptions is a specimen, viz., *Marjumia conspicabilis,* submitted later by Mr. Campbell Miles, and now incorporated in the Queensland Collection.

The specimens were received with other fossils (Ordovician), on 14/4/25, and a preliminary report was furnished, 7/5/26, which, however, was not published. Since writing this report I have been able to devote more time to the study of these fossils, and in some cases the former tentative determinations have been somewhat modified. Their generic affinities are such as to confirm the horizon in which they are found, as being of Middle to Upper Cambrian age. The genera and species herein described are as follows:—

BRACHIOPODA:—

Lingulella marcia Walcott, var. *templetonensis,* nov.
Acrothele bulboides, sp. nov.

TRILOBITA:—

Agnostus chinensis Dames.
Bathyuriscus saint-smithii, sp. nov.
Bathyuriscus nitidus, sp. nov.
Bathyuriscus olenelloides, sp. nov.
Marjumia milesi, sp. nov.
Marjumia conspicabilis, sp. nov.
Marjumia elegans, sp. nov.
Dikelocephalus dunstani, sp. nov.
Milesia templetonensis, gen. et sp. nov.

Phylum MOLLUSCOIDEA.
Class BRACHIOPODA.
Order ATREMATA.
Family OBOLIDAE.
Genus **Lingulella** Salter.

LINGULELLA MARCIA Walcott, var. TEMPLETONENSIS, nov.

(Plate XXI., Figs. 1, 2.)

Lingulella marcia Walcott, 1911, pp. 74-75, pl. xiv., figs. 3, 3*a*. Id., 1913, p. 69, pl. ii., figs. 6, 6*a*.

Observations.—This new varietal form is distinguished by its large size, compared with the type species. There are two examples in the present series. One is an internal cast of a pedicle or ventral valve, showing umbonal and lateral scars. The characteristic divergent striae of this specific form are even impressed on this cast, as was also shown in the internal shell surface figured by Walcott (*loc. cit.*) from a Chinese example. The outline of this Queensland specimen represents the internal surface of a shell of the narrower variety of *Lingulella marcia*. This agrees with the figure 6*d* of Walcott's series from the Middle Cambrian of China. The internal striae and pedicle channel are very distinctly seen, and the shell is of porcellanous whiteness on a yellow matrix.

Dimensions.—Length, 14·5 mm.; width, 11·5 mm.

The length of the typically broad form of *Lingulella marcia* from the Cambrian of China, figured by Walcott on his pl. ii., fig. 6*e*, is 3 mm. On account of the large dimensions of our specimens we are justified in regarding the Queensland form to be at least varietal to the Chinese species, and have therefore named it as a local variety.

Occurrence.—Twelve miles west of Mt. Isa, head of Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith, July, 1924.

Order NEOTREMATA.
Family ACROTHELIDAE.
Genus **Acrothele** Linarsson.

ACROTHELE BULBOIDES, sp. nov.

(Plate XXI., Figs. 3-5.)

Description.—Shell slightly wider than long. rounded to almost subquadrate. Ventral valve with a fairly long hinge-line; anterior border rounded and meeting the hinge-line at a decidedly sharp angle. Posterior sloping away to the anterior border. The tumid area occupied by a deep subquadrate fossette indicating the pedicle opening. whilst towards the hinge-line there is the usual

V-shaped depression common to the genus. The shell-structure is corneous and glossy and generally white, whilst the surface is concentrically marked with very fine growth lines. Dorsal valve slightly convex to flat, broadly rounded, with fine concentrically marked surface, the striae on which are seen to slightly undulate or even anastomose.

Dimensions.—Length of holotype (ventral valve), 3·5 mm.; width, 4 mm.; height, circ. 1 mm. Length of paratype (dorsal valve), 5 mm.; width, 5·5 mm.

Observations.—From the relative tumidity of the ventral valve it might appear that the relationship of the above species was with *Acrotreta* rather than *Acrothele.* The broadly expanding anterior area, however, shows it to belong to the type of *Acrothele* represented by Walcott's *A. matthewi,* var. *eryx,* from the Middle Cambrian of China (Walcott, 1913, p. 73, pl. iii., figs. 6, 6*a*-*h*). *Acrothele bulboides* differs in the greater tumidity of the pedicle area and in the practical absence of radial surface striae. From *Micromitra* the above form is distinct in the position of the pedicle opening, although at first sight the shells appear to belong to that genus, as indicated on the Field List supplied with this collection.

Occurrence.—Twelve miles west of Mount Isa, head of Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith, July, 1924.

Phylum ARTHROPODA.

Class TRILOBITA.

Order HYPOPARIA.

Family AGNOSTIDAE.

Genus **Agnostus** Brongniart.

AGNOSTUS CHINENSIS Dames.

(Plate XXI., Fig. 6.; Pl. XXII., Fig. 20.)

Agnostus chinensis Dames, 1883, p. 27, pl. ii., figs. 18, 19. Walcott, 1913, p. 99, pl. vii., figs. 4-6, 6*a*.

Observations.—Three pygidia occur on two of the chips under field No. 26 of the present collection. They agree specifically in having a semi-circular border with a sub-acuminate axial lobe; there is also a sub-central tubercle adjacent to a transverse and slightly curved ridge. On each side of the margin of the pygidial border, towards the posterior third, there is an obscure and blunt spine.

A species of the genus *Agnostus,* viz., *A. elkedraensis* Eth. fil., has already been recorded from the same area, by Dr. Whitehouse in his "Note on a Collection of Cambrian Trilobites from the South Templeton River, Queensland" (Whitehouse, 1927). *A. elkedraensis,* according to Etheridge jun., who described it from the Barkley Tableland, has no lateral pygidial spines, but differs

from the present species in having a transversely divided pygidial lobe with a tubercle on the anterior portion, whilst the lateral spines are more posteriorly situated. Etheridge's comparison of *A. elkedraensis* with *A. acadicus* of Hartt, shows it to be distinct from the Thornton River form here referred to *A. chinensis*.

Dimensions.—Plesiotype, length of pygidium, 2·75 mm.; greatest width, 2·5 mm.

Occurrence.—Found in whitish porcellanised rock with ironstains, Thornton River, NW. Queensland; collected by Mr. Campbell Miles.

Order OPISTHOPARIA.

Family BATHYURIDAE.

Genus **Bathyuriscus** Meek.

BATHYURISCUS SAINT-SMITHII, sp. nov.

Description.—(Based on type, collected by Mr. D. Smith.) Form of carapace roundly ovate. Head broadly rounded, with solid and lengthened genal spines extending to the line of the third thoracic ring. Glabella prominent, well-rounded in front, straight at sides. Fixed cheeks and palpebral lobes semicircular and strongly curved. Frontal limb finely lineate, increasing in strength towards the genal angles. Transverse furrows of the glabella well-marked. Neck-ring distinct, apparently without spine.

Thoracic segments twelve, narrow, with sillon. The segments of the lobe broad and well defined, with indications of a short basal spine. At junction with the axial furrows the surface of the pleura rise to tubercles which may have supported the short spines. Extremities of pleura terminate in short backwardly curved spines. Pygidium comparatively small, semicircular, consisting of four segments, with a terminal ovate axial lobe.

Dimensions.—Length of carapace, 48 mm. Width of cephalon measured at the genal angles, 35 mm. Length of cephalon, 17 mm. Length of thorax, 23 mm. Length of pygidium, 8 mm. Greatest width of axial lobe, 9·25 mm.

Observations.—The nearest related species to the above is perhaps *Bathyuriscus anax* Walcott, which occurs in the Middle Cambrian of Salt Lake Country, Utah. Although agreeing in general form and character, the present species differs from *B. anax* in having twelve instead of eight thoracic segments, and in having longer genal spines. The carapaces are often so abundant that one lies upon the other and they appear to have drifted into a closely packed pool. The rock in which they are found varies from a whitish tuff-like and silicified sediment to a similar hard rock much stained with iron, varying from yellowish to perhaps brown.

Occurrence.—This handsome species is by far the commonest trilobite in the Mount Isa Cambrian series. Twelve miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith. Also the holotype by D. Smith, per E. H. Muir (presented to the Commonwealth Collection). Named in honour of Mr. E. C. Saint-Smith.

Bathyuriscus nitidus, sp. nov.

(Plate XXI., Fig. 9.)

Description.—Carapace elongate-ovate. Cephalon rounded, paraboloid, with slender, dependent genal spines. Glabella rather narrow, long, and with four well-marked transverse furrows. Frontal limb sulcate within the margin, becoming finely grooved towards the genal spines. The fixed cheeks and the palpebral lobes wide and expanded, margined by a lunate crest. Neck-ring well developed. Thoracic segments probably eight, very narrow, the pleura terminating in sharp spines. The axial lobe is about half the width of the thoracic lobe. Pygidium unknown.

Dimensions.—Length of cephalon, 6 mm. Width at genal angles, 11 mm. Width of thorax, circ. 9·5 mm.

Observations.—This neat little species appears to find some relationship with *Bathyuriscus rotundatus* (Rom.), which is found in the middle and base of the Upper Cambrian in the Mount Stephen district, British Columbia (see Walcott, 1916, p. 346, pl. xlvii., fig. 2, 2*a*,*b*). Thus the present form has similarly sharp genal spines and thoracic margins, whilst the shape of the glabella is also identical. On the other hand our species has more widely expanded fixed cheeks.

Occurrence.—A single specimen found 12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

Bathyuriscus olenelloides, sp. nov.

(Plate XXI., Fig. 10.)

Description.—Form of carapace elongate-ovate. Cephalon broadly semicircular. Glabella roundly expanded in front, concave laterally; border of fixed cheeks strongly convex, with the palpebral lobes small and lunate. Genal spines long and divergent. Thorax of 10 segments, narrow, with sharply terminated pleura. Pygidium obscurely preserved and apparently small, rounded at extremity.

Dimensions.—Height of cephalon, 9 mm. Approximate width at genal angle, 20 mm. Length of thorax, 14 mm. Height of pygidium, circ. 3·5 mm.

Observations.—This is a much larger form than *B. nitidus*, which occurs on the same slab, and further differs from it in its

broader carapace and strongly divergent genal spines. This latter character suggested the trivial name *olenelloides*. This type of cephalon is also seen in *Bathyuriscus primus* (Walcott, 1916, p. 352, pl. xlvi., fig. 6*d*), from the Lower Cambrian, Alberta, Canada, which otherwise differs in having a shorter carapace with fewer thoracic segments.

Occurrence.—A single individual on a slab of white porcellanous shale with *B. nitidus*, sp. nov., 12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

Family OLENIDAE.

Genus **Marjumia** Walcott.

MARJUMIA MILESI, sp. nov.

(Plate XXI., Fig. 11.)

Description.—Cephalon (glabella and fixed cheeks only). Glabella elongate-ovate, broad anteriorly, and at the base with moderately well-marked transverse furrows. Border of fixed cheeks subcircular with a small palpebral lobe at the posterior lateral angle. Pygidium transversely ovate, the lateral margin curving outwardly and downwards, forming conspicuous falcate or sickle-shaped spines. Posterior lateral margins continued to basal extremity, entire but for a small blunt posterior spine on each side of the flattened concave border of the pygidial extremity. The pygidium has four segments. Pygidial axis moderately convex, flattened towards the posterior excepting at the extreme end, which is swollen. The flattened pygidial border below the extremity of the pygidial axis has the surface finely and concentrically furrowed as in both *Bathyuriscus* and *Dikelocephalus*.

Dimensions.—Height of cephalon (paratype), 13 mm. Glabella at widest part, 6·5 mm. Pygidium (holotype), length, 12·75 mm. Greatest width above principal spines, 27 mm. Length of pygidial axis, 8·5 mm. Width of axis at junction of thorax, 8·5 mm. Width of posterior extremity, 5 mm. Width of pygidial border at posterior extremity, 4·25 mm.

Observations.—Several of the species of the genus *Marjumia* which Dr. Walcott has described from the Middle Cambrian of Millard County, Utah (Walcott, 1916, p. 402, pl. lxv., fig. 3*b*), have points of agreement with the above species, but differ in some essentials. Thus the pygidia figured by that author as *Marjumia callas* have the lateral spines falcate, but the pygidial extremity is rounded and not obtusely concave. Another species, which was not determined by Walcott, but placed under *Bathyuriscus* and compared with *Marjumia callas* (Walcott, 1916, p. 348, pl. lxv., fig. 5), and in the text with *Bathyuriscus adaeus,* is even closer in pygidial characters.

Occurrence.—12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

MARJUMIA CONSPICABILIS, sp. nov.

(Plate XXII., Fig. 13.)

Description.—Holotype, consisting of large part of thorax and pygidium, shows the carapace to be of large size, and of a long-ovate form. The thorax has the lateral margins broadly rounded, and the 14 segments of the genus are represented. The longitudinal axis is wide, and tapers only slightly towards the pygidium. It is on this depressed area that the ends of the pleura separate into salient backwardly directed spines. The last of the series belongs to the anterior segments of the pygidium, where it represents the falcate spine typical of the genus *Marjumia.* The thoracic segments are fairly narrow, and the pleura are each marked by a conspicuous diagonal sillon. The pygidial border in the specimen is not sufficiently well preserved to indicate the number of spines it carries, but there is an indication of at least one pair of spines below the anterior, falcate ones. The pygidial margin is finely, concentrically striate, as in *M. milesi.*

Dimensions.—Length of thorax, circ. 34 mm. Greatest width of carapace, 47 mm. Length of pygidium, circ. 11 mm. Greatest width, 26 mm.

Observations.—Apparently the only species comparable with *Marjumia conspicabilis* is *M. typa* Walcott. The carapace of the Shepherd Creek species, however, is more broadly ovate, and the marginal depression of the pleura and pygidium is more pronounced. The longitudinal axis in *M. typa* is much narrower, and the axial furrows are nearly straight. The spinose ends of the pleura in *M. typa* are sharper and more salient than in *M. conspicabilis,* where they curve rather suddenly towards the posterior. The axis of the pygidium in *M. typa* is proportionately longer than in *M. conspicabilis* and its marginal border has apparently a large number of spines.

Occurrence.—Shepherd Creek, near Miles Creek, north branch of the Templeton River, NW. Queensland; presented to the Geological Survey of Queensland by Mr. Campbell Miles.

MARJUMIA ELEGANS, sp. nov.

(Plate XXII., Figs. 14-16.)

Description.—Carapace rather small, broadly ovate anteriorly, tapering posteriorly; cephalon broadly semi-circular, with a pyriform and anteriorly expanded glabella. Outer limb grooved internally, and finely longitudinally, sulcate towards the genal angles. Genal spines moderately long, dependent. Thorax consisting of 14 segments. Pleura comparatively narrow, grooved diagon-

ally, spinose at the curved extremities. Pygidium comparatively small, consisting of four segments, and bearing four pairs of lateral, somewhat hook-shaped spines. Axial furrows somewhat deeply impressed and straight.

Dimensions.—Length of carapace, 27 mm.; width of cephalon, 21 mm. Greatest width of thorax, 18 mm. Length of pygidium, 6 mm.

Observations.—This species is perhaps the commonest of the genus here described, and the holotype has been selected from a complete carapace (No. 13A, Queensland Collection). The diagnostic characters have been based on additional specimens, among which are some well preserved cephala and pygidia. In the pygidial characters the species also resembles *M. typa* Walcott, already referred to, but the carapace, as a whole, is a rather different form.

Occurrence.—12 miles west of Mount Isa, at the head of the Templeton River. Also occurring in a collection from Mr. Campbell Miles, from Shepherd Creek, near Miles Creek, north branch of Templeton River.

Family DIKELOCEPHALIDAE.

Genus **Dikelocephalus** Owen.

DIKELOCEPHALUS DUNSTANI, sp. nov.

(Plate XXII., Figs. 17, 18.)

Description.—Based on remains of cephalon and pygidium. Cephalon, large, broad, the cranidium showing an expanded glabella, extending to the frontal margin. On either side, the frontal limb gradually expands towards the genal angle. The glabella with four transverse furrows. Palpebral lobes of the fixed cheeks wide and strongly curved. Pygidium broad, almost flabellate, with a short pygidial axis, almost triangular in outline, with four segments. Marginal border of the pygidium broad in outline and conspicuously incised with fine linear grooves. At the lateral posterior angles there are two large falcate spines which more closely approximate to one another than in *D. minnesotensis*. On the posterior segment of the pygidial axis is an indication of an incipient spine, sometimes also seen in the genus *Saukia*.

Dimensions.—Height of cranidium, 24 mm.; width of cranidium, including palpebral lobes, 30 mm. Length of pygidium, measured from the tips of the spines, 22 mm. Width of pygidium, circ. 44 mm. Average width of marginal flange, 8 mm.

Observations.—This species resembles *D. minnesotensis* Owen, in general characters. The glabella, however, is more globosely expanded in the present species, whilst the pygidial spines are situated near the axis. This species is named in honour of the

Government Geologist of Queensland, Mr. B. Dunstan, F.G.S., through whose courtesy I received the fossils for reporting upon.

Occurrence.—Thornton River, NW. Queensland; collected by Mr. Campbell Miles.

Genus **Milesia**, gen. nov.

(For generic characters, see Observations *infra.*)

Milesia templetonensis, sp. nov.

(Plate XXII., Fig. 19.)

Description.—Holotype, of a nearly complete specimen. General form elongate ovate. Cephalon transversely ovate, showing cranidium with large palpebral lobe. The frontal limb is wanting, but the free cheeks are well represented in outline by a sunken impression of a broad head-shield with short and stoutly falcate genal spines. The axial lobe with indication of the two basal transverse furrows, the posterior furrow strong, extending across the glabella. Thorax with 12 well-marked segments. Axial lobe moderately convex. Pleural lobes flattened, each segment having a distinct transverse furrow to the spinous margin. Pygidium semicircular, well rounded basally, with a deep, depressed flange radially furrowed and transversely wrinkled, and with traces of the strong pygidial spine near thoracic suture. Axial lobe of pygidium tapering distally to a point and pinched or rigid at apex. Lateral lobes of pygidium flattened, numbering about five.

Dimensions. — Approximate height of cephalic shield, 20 mm.; width of cephalic shield, including free cheeks, 42 mm. Height of thoracic series, 34 mm. Greatest width of thorax, 40 mm. Height of pygidium, circ. 18 mm. Greatest width of axial lobe, 13 mm.

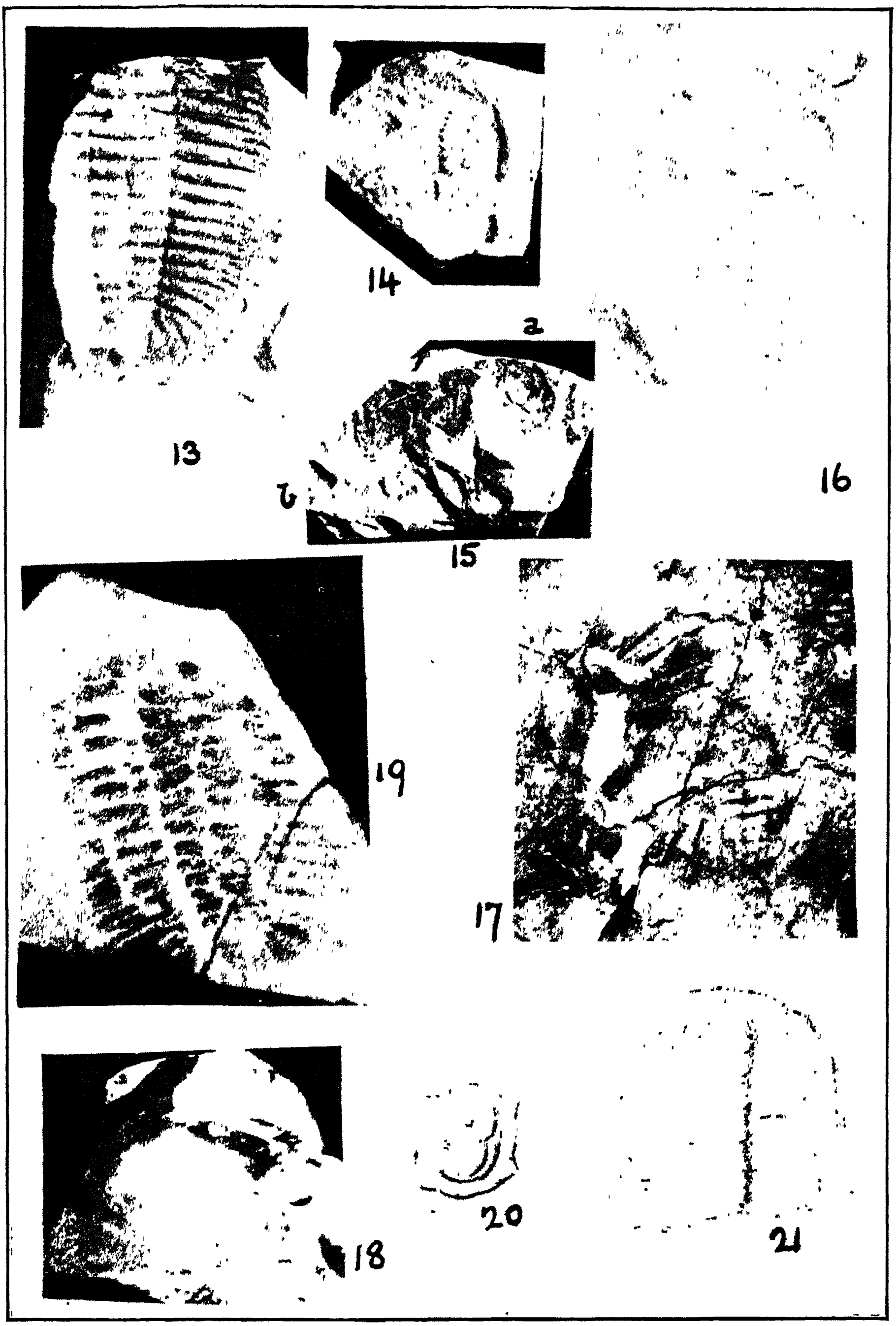
Observations.—This handsome form shows some relationship to *Dikelocephalus,* but it is better to refer it to a new genus. This is named in honour of one of the discoverers of this interesting collection, Mr. Campbell Miles.

The furrowed glabella and the large number of thoracic segments—12—separate *Milesia* from *Bathyuriscus,* which it otherwise resembles. The expanded base of the pygidium also agrees with *Dikelocephalus.* In *Marjumia* the glabella is narrower and not so conspicuously furrowed, though the number of thoracic segments agrees in that particular. The genal spines are not so slender and prolonged as in *Dikelocephalus,* but more nearly resemble those of *Bathyuriscus.*

Occurrence.—Preserved in sub-cherty shale of a whitish tint, iron-stained on joints and showing as a brown chert on a fractured surface. 12 miles west of Mount Isa, at the head of Templeton River, NW. Queensland (Queensland Geol. Survey Coll.).

F.C. photo.

Cambrian Fossils. Mt. Isa, Queensland.



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EXPLANATION OF PLATES.

PLATE XXI.

Fig. 1.—*Lingulella marcia* Walcott, var. *templetonensis,* nov. Pedicle valve. × circ. 1½.

Fig. 2.—*L. marcia* Walcott, var. *templetonensis,* nov. Dorsal valve. × circ. 2.

Fig. 3.—*Acrothele bulboides,* sp. nov. Holotype. Pedicle valve (on right). × 2.

Fig. 4.—*A. bulboides,* sp. nov. Dorsal valve. × circ. 2.

Fig. 5.—Slab showing group, mainly pedicle valves, of *A. bulboides.* × 2.

Fig. 6.—*Agnostus chinensis* Dames. Two pygidia. × circ. 2.

Fig. 7.—*Bathyuriscus saint-smithii,* sp. nov. Holotype. Natural size.

Fig. 8.—*B. saint-smithii,* sp. nov. Slab with two carapaces. Natural size.

Fig. 9.—*Bathyuriscus nitidus,* sp. nov. Holotype. Circ. natural size.

Fig. 10.—*Bathyuriscus olenelloides,* sp. nov. Holotype. Circ. natural size.

Fig. 11.—*Marjumia milesi,* sp. nov. Holotype, ¾ natural size.

Fig. 12.—*M. conspicabilis,* sp. nov. Pygidium, Natural size.

PLATE XXII.

Fig. 13.—*Marjumia conspicabilis,* sp. nov. Holotype. Natural size.

Fig. 14.—*Marjumia elegans,* sp. nov. Paratype. Natural size.

Fig. 15.—*M. elegans,* sp. nov.; *a,* cephalon; *b,* pygidium. Natural size.

Fig. 16.—*M. elegans,* sp. nov. Holotype. × circ. 2.

Fig. 17.—*Dikelocephalus dunstani,* sp. nov. Holotype. Natural size.
Fig. 18.—*D. dunstani,* sp. nov. Paratype, cephalon. Natural size.
Fig. 19.—*Milesia templetonensis,* gen. et sp. nov. Holotype. Natural size.
Fig. 20.—*Agnostus chinensis* Dames. Pygidium. Enlarged drawing. × 3.
Fig. 21.—*Bathyuriscus nitidus,* sp. nov. Holotype. Enlarged drawing. × 6.

NOTE.—The holotypes and paratypes are in the Queensland Geological Survey Collection, with the exception of the holotype of *Bathyuriseus saint-smithii,* which is in the Commonwealth Collection, and the paratype of *Marjumia elegans* Chapm. (pl. xxii., fig. 14) which is in the author's collection.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. XV.—*On a New Species of Capulus found attached to a Pterygotus Carapace.*

By FREDK. CHAPMAN, A.L.S., F.G.S., etc.

(Commonwealth Palaeontologist, National Museum, Melbourne.)

(With Plate XXIII.)

[Read 13th December, 1928; issued separately 8th April, 1929.]

Introduction.

Some years ago Sir Frederick McCoy (1899) described a new species of *Pterygotus* (*P. australis*) from the hard blue shale of South Yarra, near Melbourne. The rock in which it was found belongs to the lower or Melbournian stage of the Silurian.

This specimen of *Pterygotus* is represented by both the holotype of a somite figured by McCoy and the counterpart on which the shells of *Capulus* are present. These specimens are in the National Museum collection.

The *Pterygotus* somite measures, post-anteriorly, 61 mm., and it has an estimated breadth of 165 mm. (6½ inches).

Soon after my arrival in Melbourne, in 1902, whilst examining the holotype I noticed that the surface of the carapace bore, besides the conspicuous scale-like markings, several depressed ovate areas which were not noted in McCoy's description. A wax or plasticine impression from these showed a valve in relief which then seemed to be referable to either *Pholidops* or *Orbiculoidea,* the latter genus as well as *Crania* being already known as a brachiopod commensal on cephalopod shells from the Palaeozoic of the United States of America.

Lately, whilst in conversation with Sir Edgeworth David on the subject of his recent discoveries of Eurypterids in the Proterozoic rocks of South Australia, he mentioned the occurrence of generally similar commensal limpet-like fossils. My interest in the Silurian specimens here described was thus revived.

The chief obstacles in referring the present fossils either to *Crania, Pholidops* or *Orbiculoidea* are:—

1. The absence of a cemented valve, or trace thereof.
2. The irregular growth stages of the shell surface, which in *Pholidops* are evenly developed.
3. The absence of a pedicle opening either of *Crania* or *Orbiculoidea.*

The only form to which we can reasonably assign the present specimens seems to be that of a member of the gasteropod genus *Capulus,* which ranges from Cambrian to Recent. I have been greatly helped in this comparison and diagnosis by finding a recent specimen of *Chlamys bifrons* from South Australia in the Dennant Collection, the valves of which are peppered over with small attached shells of an allied genus, *Hipponix*. A common character of both this recent—*H. conicus* (Schumacher) (May, 1921, 1923)—and the Silurian examples is the cleared area around the shell, a feature also to be noticed with living limpets.

It is very remarkable to find so close a resemblance in form, external structure and nearly equal dimensions, in the two Silurian and living genera and species.

In selecting his holotype of *Pterygotus* from the two specimens (counterparts) discovered by F. P. Spry in the Silurian mudstone, McCoy seems to have been influenced by the character of the ornament of the carapace. In the holotype this is a salient squamation, and agrees in the main with that seen in well-preserved specimens from England, North America and Bohemia. Apart from this general character of salient squamation, there appear parts of the carapace in other specimens which have an impressed ornament. So that my selection of the counterpart of McCoy's type of the South Yarra specimen of *Pterygotus* as the actual positive surface, on account of the appearance of the shells of *Capulus* in relief, is not without reason.

Description.

Class GASTEROPODA.

Family CAPULIDAE.

Genus **Capulus** Montfort.

Capulus melbournensis, sp. nov.

(Plate XXIII., Fig. 1.)

Shell ovate, expanding in ephebic stage. Apex moderately high to depressed and incurved. Concentric growth lines distinct, with strong growth stages at intervals. In some examples an apical ridge extends down the middle of the shell. The shell is seated in a depressed area on the carapace of *Pterygotus australis,* similar to that seen in living examples of the allied genus *Hipponix* attached to *Chlamys* and other bivalves.

Length of holotype, 3·25 mm. Greatest width, 2·25 mm. Height, circ. 1 mm.

Occurrence.

Eleven specimens attached to the carapace of *Pterygotus australis* McCoy. Silurian (Melbournian). Domain Road, South

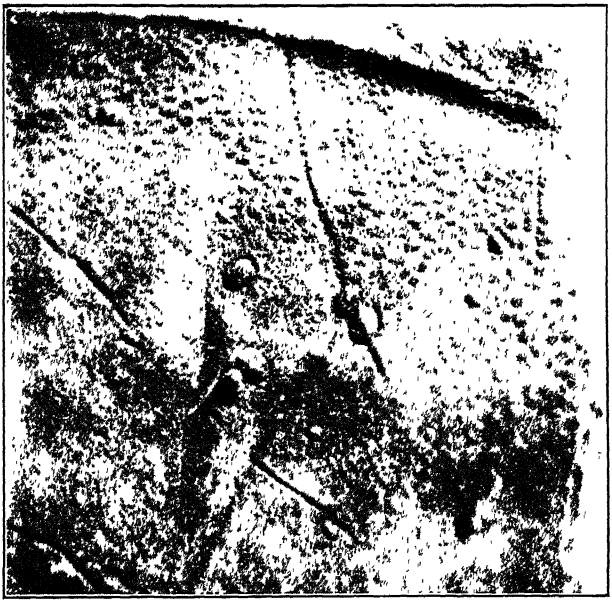
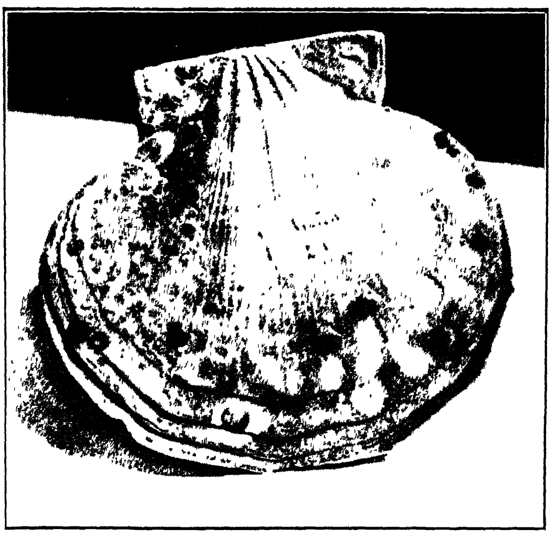


Fig. 1.



F.C. photo.

Fig. 2.

Sessile Gasteropods: Capulus (Silurian), Hipponix (Recent).

Yarra (main sewer tunnel). Found by F. P. Spry, and donated to the National Museum. Registered No. of present counterpart No. 1085. Registered No. of McCoy's Holotype, No. 577.

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EXPLANATION OF PLATE XXIII.

Fig. 1.—Portion of somite of *Pterygotus australis* McCoy, with attached shells of *Capulus melbournensis*, sp. nov. Silurian (Melbournian). S. Yarra. × circ. 2.

Fig. 2.—*Chlamys bifrons* (Lam.). Living, S. Australia. Valves with attached shells of *Hipponix conicus* (Schum.). 2/3rds natural size.

[PROC ROY SOC. VICTORIA, 41 (N S), PT. II, 1929]

ART. XVI.—*Notes on and Additions to Australian Fossil Polyplacophora (Chitons).*

By EDWIN ASHBY, F.L.S., etc.

(Communicated by F. Chapman, A L S)

(With Plate XXIV.)

[Read 13th December, 1928; issued separately 8th April, 1929]

Introduction.

Mr. Francis A. Cudmore has placed in my hands for description a large number of valves of Fossil Chitons, both from the Table Cape beds in Tasmania and the Balcombian beds in Victoria. The Rev. George Cox, of Mornington, and Dr. H. J. Finlay, of Dunedin, N.Z., have also permitted me to study important material from Balcombe Bay. Two species are added to the fossil fauna: one, a unique example of *Ischnochiton* (*Heterozona*) *cariosus* Pilsbry, is the first fossil representative of its genus to be found in Australia; the other discovery, for which the new genus *Oöchiton* is instituted, is still more remarkable, the nearest apparent relatives being two rare deep water forms from Cape Horn and Antarctica, one of which is figured for comparison. A discussion of the systematic position of the new discoveries is given and a classified list of the Australian Fossil Polyplacophora is furnished.

Systematic Description.

LORICA COMPRESSA Ashby and Torr, 1901.

From the Crassatella Beds, Table Cape, Tasmania, Mr. Cudmore has taken complete, or portions of, 24 median valves and three portions of anterior valves, one almost complete, all referable to the above species.

LORICA COMPRESSA var. AFFINIS Ashby and Torr, 1901.

In the collection is one median valve and two fragments of median valves of this variety in which the longitudinal ribbing is much more widely spaced than is the case in *L. compressa*, s.str.

LORICA CUDMOREI Ashby, 1925.

From the same bed as the foregoing two imperfect median valves of this species were taken.

Mr. Cudmore has found 32 valves or portions thereof belonging to the genus *Lorica* from one bed. It not only evidences that the genus *Lorica* was numerically very strong in the ancient sea in which this Crassatella bed was laid down, but also that this genus of Chitons was almost the only one represented in association with the *Crassatella*. In the seas of to-day the genus *Lorica* is but poorly represented as compared with other groups of Polyplacophora, and it is only recorded from Australasian waters.

LORICELLA GIGANTEA Ashby and Torr, 1901.

(Plate XXIV., Fig. 9.)

One beautiful example of the head valve of this species is in the collection; it was taken from the Lower Bed, Table Cape, Tertiary (Janjukian).

In the original description the locality was given as Mornington, although thought to have been a mistake. This, the second example of this valve, is a small replica of the holotype, measures $24 \times 12 \cdot 5$ mm., and settles the question as to the true locality of the original find. The median valve described by Hull as *Loricella magnifica,* which, as I have already indicated, is referable to this species, was also from Table Cape: I therefore indicate the Lower Bed, Table Cape, as the type locality and horizon.

Oöchiton, n. gen.

This new genus is proposed for the reception of a new and unique form which is herein described under the name *Oöchiton halli,* n. sp., which species I designate as type of this genus.

The median valve has in common with the genus *Notochiton* a very strongly carinated shell with very steep side-slope, the sutural laminae joined across the middle line, insertion plate in median valve broad, edge smooth, slits 1/1, broad and deep. It differs from *Notochiton* in the absence of regular longitudinal ribbing, and possesses peculiar ovate pustules which stand erect in irregular rows or widely scattered over the whole of the tegmentum; these pustules apparently are associated with the nerve fibres, for most of them have a minute aperture at the summit, and differs also in the greater width of the insertion plate. The name is suggested by the peculiar sculpture which suggests strings of minute eggs.

Since the above definition was written, the tail valve has been discovered. This valve differs widely from the genus *Notochiton,* and, to the best of my belief, is quite unique in its characters. The

upturned and greatly thickened extremity, with the deep sinus immediately behind the mucro and the extended fold of the tegmentum into this sinus, in a limited degree, resemble the genus *Lorica;* the entire absence of the insertion plate immediately behind the mucro together with the greatly thickened extension of the insertion plate laterally with its single slit on either side, faintly reminds one of some members of the Mopaliidae.

The contour of the anterior valve is remarkably like that of *Notochiton mirandus* Thiele, the insertion plate is also similar in being grooved and bevelled, but the slits in *Oöchiton* are proportionally broader. Whereas *Notochiton mirandus* possesses ray-ribs corresponding with the slits, the species under discussion has no ray-ribs and no correspondence between the sculpture and the slits. It will be seen that both the anterior and the median valves show some affinity with the genus *Notochiton,* but the tail valve is strikingly dissimilar and unique. I consider the genus *Oöchiton* more primitive than the genus *Notochiton,* but it might well be placed immediately preceding that genus.

OÖCHITON HALLI, n.sp.

(Plate XXIV., Figs. 1*a,b;* 2*;* 3*a-c;* 8*a,b.*)

Mr. F. A. Cudmore has placed in my hands two median valves of an entirely new species of Chiton; the one I am making the holotype was found by him at Balcombe Bay, near Mornington, Victoria, Tertiary (Balcombian); the other is also in Mr. Cudmore's collection, and was collected by the late Dr. T. S. Hall at Belmont, Geelong, Victoria, Tertiary (Barwonian), and is separately described herein.

Since writing the following description I have received from the Rev. George Cox, of Mornington, through Mr. R. A. Keble, the Palaeontologist of the National Museum, Melbourne, a tail valve and some additional median valves of the same species. Mr. Cox writes as follows: "The tail valve and several median valves were found [in the Balcombian Beds] at Mornington, by a lad aged 12 years, named Evan Chitts; two median valves and the tail valve were washed out of one cubic inch of clay, and may have belonged to the same animal."

Still more recently Dr. H. J. Finlay of Dunedin, N.Z., has sent me an example of the anterior valve of *Oochiton halli,* which had been collected by himself in the Balcombian beds at Mornington. He is generously allowing me to keep this specimen, which I am describing hereunder as the type of the head valve of this species: up to the present this example of the head valve is unique.

I am naming this interesting species at the suggestion of Mr. Cudmore after the late Dr. T. S. Hall, the discoverer of the first median valve found.

Median valve.

Holotype, Balcombe Bay, Victoria. — Pl. (XXIV., Fig. 1*a,b*). Strongly carinated, very elevated, side-slope straight and steep, angle of divergence 70°, surface smooth and polished, areas indistinguishable, one or two shallow growth lines parallel with the margin towards the girdle. The ornamentation is unique, and consists of six longitudinal broken strings of minute bead-like pustules; the pustules are ovate, and together resemble strings of minute white eggs, which feature has suggested the name of the genus. The first row nearest the jugum has 12 of these pustules; the second has nine only, traverses only half way across the pleural area and is bowed upwards; the third has 14 pustules; the fourth has 9; the fifth has 10; and the sixth has only 2 pustules. It must be noted that all these rows have gaps, the string not being continuous, but this is in some places undoubtedly due to the breaking off of some pustules. The dorsal ridge is slightly raised, anteriorly a little broader than at the beak, and in a faint degree is subgranulose. The foregoing is as seen under a simple lens, $\times$ 20.

Under a Zeiss binocular microscope, $\times$65, some very interesting features are made clear. The whole of the surface of the shell is highly polished, and everywhere thickly perforated with megalopores. It is also transversely, concentrically crossed by numerous growth grooves or lines, these running across the jugum from side to side. To these grooves is due the apparent subgranulose appearance of the dorsal ridge. The bases of detached pustules are visible, the pustules themselves are definitely ovate, attached by the smaller end and almost vertical; each pustule has a small perforation at the summit, looking like a black dot, which is a little larger than the megalopores of the normal surface of the shell; except for this aperture the pustules are solid, not hollow, as in *Protochiton*. The channel connecting nerve fibres with the black dot can be seen in places where the pustules have been broken. Corresponding with the rows of pustules is an irregular series of deep pits with a black, probable eye-dot at the bottom; these rows of pits are on the lower and outer side of the pustules, and are overhung and almost hidden by these. The perforations at the base are much larger than the megalopores, and therefore must have functioned much like what are known as "eyes" in recent species. This description is taken from the right side of the shell; the other had met with some injury during life, and the process of mending has caused the outer part of the lateral area to bend upwards, and the strings of egg-shape pustules have somewhat merged into one another. The inside of the valve is white, and the tegmentum is folded over at the beak, the margin of the fold being coarsely pustulose.

Dimensions.—The holotype, median valve, is 4·5 mm. in width and 3·75 mm. in length; angle of divergence, 70°.

Paratype, Belmont.—(Pl. XXIV., Fig. 2). Median valve, beaked, carinated, side-slope very steep, dorsal area arched except near the beak, where it is narrowed to a mere ridge, smooth except for several narrow ridges unsurmounted by pustules, separating this area from the pleural. The character of the strings of egg-like pustules is similar to that of the type, but the rows are shorter and in places a narrow ridge connects widely-spaced pustules; near the insertion plate, grains are scattered. The sutural laminae are broken, but are joined across the centre line; the lateral area is separated from the pleural by a shallow diagonal fold. The colour of the tegmentum is silvery grey, the pustules opaque white. The pitting, although present, does not appear to be associated with the pustules, as is the case in the holotype. Interior creamy white, insertion plate undamaged on one side, teeth sharp, slits 1/1, well-defined and broad, callus imperceptible, tegmentum extensively folded over at the beak forming a "pocket." This median valve, Nat. Mus. No. **13497, is** longitudinally narrow, measuring 4 × 3 mm.; dorsal area without pustules.

Paratypes, Balcombe Bay.—No. 1 measures 4 25 × 3·75; No. 3 certainly has the articulamentum joined across the middle line between the sutural laminae; No. 4 is imperfect, has a V-shaped notch in the articulamentum between the sutural laminae; No. 5 is fragmentary, dorsal area ornamented with egg-shaped pustules but without raised dorsal ridge; No. 6 is a fragment only.

Tail valve.

Paratype, Balcombe Bay. (Type of tail valve.)—(Pl. XXIV., Fig. 3*a-c.*). Small, measuring longitudinally 2·75 mm., laterally 2·25 mm., very strongly carinated; mucro at the posterior margin or more correctly subposterior, because the tegmentum is bent over at the mucro and turned down vertically; the portion immediately behind the mucro is concave and in this cavity or sinus, are two of the egg-shaped pustules common to the sculpture of the rest of the tegmentum; from the mucro is a raised diagonal rib or fold, the strings of egg-shaped pustules of the pleural area are continued across this fold to the posterior edge of valve. This valve is upturned at the mucro and the extremity very much thickened, the insertion plate here is subobsolete, and reduced to a mere callus or ridge behind the mucro, but on either side the insertion plate is developed into a highly thickened extension of the articulamentum with one diagonal slit on either side, and in addition on one side a supplementary groove, but not a true slit. The sutural laminae are well developed, the sinus between being very narrow, and are joined to the thickened posterior insertion plate by a broad extension of the articulamentum which is suggestive of the Acanthochitonidae.

Anterior valve.

Paratype, Balcombe Bay. (Type of anterior valve).—(Pl. XXIV., Figs. 8*a,b*.). Valve highly elevated, apex slightly recurved, anterior slope very steep and concave (due to recurved apex). The ornamentation consists of strings of egg-like pustules similar to those in the other valves; the arrangement is generally speaking longitudinal, the strings commencing at the posterior margin and continuing to the insertion plate with considerable irregularity, several strings bifurcate, and in some places there are short intermediate rows; the strings or rows of pustules do not seem to have any relationship with the slits in the insertion plate.

Articulamentum, or inner layer of shell creamy white, highly polished, smooth, without any grooves; the tegmentum infolded at the apex, this infolded portion is thickly studded with the egg-like pustules; the insertion plate is well produced, perfect, except for a few minute chips; slits 7, broad and short, spacing irregular; the upper side of the insertion plate is numerously grooved, the plate is broad and proportionally thick, but the upper edge is bevelled off, so that the actual edge is sharp, the grooves not continuing to the inner edge. Valve measures $4{\cdot}5 \times 2{\cdot}25$ mm.

NOTOCHITON MIRANDUS Thiele.

(Plate XXIV., Figs. 4, 5, 6*a,b*.)

(*N. mirandus* Thiele, Subantarktischen Chitonen, pp. 12, 13.)

In the preparation of this paper comparisons have had to be made with this species, of which I have in my collection a cotype given to me by Major Dupuis. Pilsbry does not refer to it, Thiele (in *Revis. des Syst. der Chitonen*, p. 107) neither figures nor describes it, making a bare reference and stating that Edgar Smith considered it a *Chctopleura*, but Thiele considers it allied to the genus *Nuttallochiton*, and is probably correct. For purposes of comparison with *Oöchiton halli*, n. sp., figures are given.

ISCHNOCHITON (HETEROZONA) CARIOSUS Pilsbry, 1892.

(Plate XXIV., Fig. 7.)

The Rev. George Cox has sent me a single median valve of the above *Ischnochiton*, collected by Master Evan Chitts in the Balcombian Beds at Mornington. This is the first true record[1] of the discovery of a fossil *Ischnochiton* in Australia.

This example appears to have a well-defined diagonal rib, and for that reason I at first thought it would likely prove to be a new species, but on careful examination I find that this apparent

1.—F. Chapman was in error when he referred *Protochiton granulosus* to this genus (*Proc. Roy. Soc. Vic.*, n.s., xx (2), pp. 218-220, 1908).

feature is due to a slight wearing of the anterior of the raised lateral area. As compared with a half-grown example from Marino in South Australia, in which the valves are of a corresponding size, I find the sculpture similar, though a little more deeply cut, in this respect corresponding with the form from Western Australia, but it differs slightly in that the infolding of the tegmentum under the jugum is about double the width as compared with the Marino example, but in the lateral extension of this infolding it is similar. There are no differences to be distinguished in this valve to justify separation, but such may be revealed when fossil end valves are discovered. The fossil valve measures 5·5×2·25 mm.

Discussion on Classification.

I have retained the genera *Lorica* and *Loricella* under Pilsbry's subfamily Liolophurinae, while recognising that this is not their true setting. Thiele found that the radula showed relationship with the Ischnochitonidae, and treated these genera as advanced forms of that group, but I feel that more work needs to be done on characters other than that of the radula, before their true niche in the Natural Taxis can be determined. I therefore retain them in the setting in which Pilsbry placed them, until the study of this problem, from the points of view suggested above, supplies added data upon which we may form a considered opinion.

All students of the Polyplacophora are greatly indebted to Dr. Thiele for the specialized work he has done in the radula of that order. He has laid a good foundation, and it is unfortunate that since the production of his valuable work, " Revision des Systems der Chitonen," no material work has been done on the radula of this group. One should hesitate to accept too hastily conclusions based chiefly on one feature alone, until such time as other supporting features have been studied and made known.

Thiele has pointed out that in the family Lepidopleuridae there is some variation in the characters of the radula. Iredale and Hull have assumed that this discovery of Thiele's means that the absence of insertion plates and other accepted primitive characters, are the result of degeneracy, and have founded their classification on this assumption. Thiele himself drew no such conclusion from his discovery, and proposed a suborder, Lepidopleurina, for this group, numbering it (I.). I feel sure a right conception of taxonomic values will endorse Thiele in his treatment, and I have suggested that the Chitons living in the seas of to-day have not arisen from primitive stock in one phylum alone, but through more than one. This I have demonstrated in the case of the Acanthoid group, and have expressed the opinion that the existence of divergences in the radula of members of the Lepidopleuridae is

important evidence that gathered together in this group are the progenitors of more than one phylum that have developed along parallel lines.

The discovery, in addition to the median ones, of the end valves of the fossil *Protochiton granulosus* (Ashby and Torr), has made it quite clear that this species could not have been derived through any members of the Lepidopleuridae, and its evident relation to the Acanthoid Group of Chitons makes necessary a partial revision of our previous conception of the Classification of Polyplacophora.

This revision was foreshadowed in my Phylogenetic Diagram, page 75 (1.c.); I have endeavoured in the following Classification List to give expression to this revised conception, made necessary by the recent discoveries named above.

The proposal of Iredale and Hull to substitute the word "Loricates" for the universally used "Chitons," dating as this latter does from the days of Linné, surely can commend itself to no one. The proposal to substitute the word "Loricata" for "Polyplacophora," and "Cryptoconchidae" for "Acanthochitonidae," is not compulsory, and surely can serve no good purpose. The law of priority does not apply to ordinal and family names; also the use of the term "Type Genus" is understood by most workers to mean "typical genus," which the specialized form *Cryptoconchus* certainly is not.

Since the issue of my Monograph on Australian Fossil Polyplacophora, Iredale and Hull have described the cast of a Chiton from the Permo-Carboniferous beds of Bundanoon, New South Wales, and have called it *Permochiton australianus*. This specimen is a very interesting one, in face of the fact that Etheridge's *Chelodes calceoloides* has already been disallowed, for although its true character is still in doubt, there seems a consensus of opinion that it is not a representative of the order Polyplacophora; *Permochiton australianus* comes from the oldest series of beds in which Chitons have yet been found in Australia. These gentlemen suggest some resemblances between *P. australianus* and the genera *Ischnochiton* and *Lepidopleurus*, but judging from their figures I can see no resemblance, though certainly there is a general resemblance to the Palaeozoic genus *Helminthochiton*, and it is quite natural to suppose that members of that genus would persist from the Carboniferous into the Permo-Carboniferous.

Classification of Australian Fossil Polyplacophora.

Class AMPHINEURA.

Order POLYPLACOPHORA (Blainville em.) Gray, 1821.

[PRIMITIVE.]

Suborder EOPLACOPHORA Pilsbry, 1900.

[FOSSIL ONLY.]

Family GRYPHOCHITONIDAE Pilsbry, 1900.

Genus PERMOCHITON Iredale and Hull, 1926 (without definition).

Permochiton australianus Ire. and Hull, 1926.

Suborder PROTOCHITONINA Ashby, 1928.

Family PROTOCHITONIDAE Ashby, 1925.

Genus PROTOCHITON Ashby, 1925.

Protochiton granulosus (Ashby and Torr, 1901).

Family ACANTHOCHITONIDAE Hedley, 1916.

Subfamily AFOSSOCHITONINAE Ashby, 1925.

Genus AFOSSOCHITON Ashby, 1925.

Afossochiton cudmorei Ashby, 1925.

A. rostratus (Ashby and Torr, 1901).

[ADVANCED.]

Subfamily ACANTHOCHITONINAE Ashby, 1925.

Genus ACANTHOCHITON Gray em., 1821.

Acanthochiton chapmani Ashby, 1925.

Subfamily CRYPTOPLACINAE Thiele, 1910.

Genus CRYPTOPLAX Blainville, 1818.

Cryptoplax pritchardi Hall, 1905.

C. gatliffi Hall, 1905.

[PRIMITIVE.]

Suborder LEPIDOPLEURINA Thiele, 1910.

Family LEPIDOPLEURIDAE Pilsbry, 1892.

Genus LEPIDOPLERUS Risso, 1826.

Lepidopleurus magnogranifer Ashby, 1925.

[ADVANCED.]

Suborder CHITONINA Thiele, 1910.

Family CALLOCHITONIDAE Thiele, 1910.

Subfamily TRACHYDERMONINAE Thiele, 1910.

Genus NOTOCHITON Thiele.
Notochiton mirandus Thiele. Recent.
N. hyadesi Rochebrune, 1889. Recent.

Genus OÖCHITON Ashby, n. gen.
Oöchiton halli Ashby, n. sp.

Family MOPALIIDAE Pilsbry, 1892.

Genus PLAXIPHORA Gray, 1847.
Plaxiphora concentrica Ashby and Torr, 1901.

Family ISCHNOCHITONIDAE Pilsbry, 1892.

Subfamily ISCHNOCHITONINAE Pilsbry, 1892.

Genus ISCHNOCHITON Gray, 1847.

Subgenus HETEROZONA (Cpr. MS.) Dall, 1878.
Ischnochiton (Heterozona) cariosus Pilsbry, 1892.

Subfamily CALLISTOPLACINAE Pilsbry, 1892.

Genus CALLISTOCHITON Carpenter, 1882.
Callistochiton meridionalis Ashby, 1919.

Family CHITONIDAE Pilsbry, 1892.

Subfamily CHITONINAE Pilsbry, 1892.

Genus CHITON Linné, 1758.

Subgenus RHYSSOPLAX, Thiele, 1893.
Chiton (Rhyssoplax) fossicius Ashby and Torr, 1901.

Subfamily LIOLOPHURINAE Pilsbry, 1893.

Genus LORICA H. and A. Adams, 1852.
Lorica compressa Ashby and Torr, 1901.
L. compressa var. *affinis* Ashby and Torr, 1901.
L. cudmorei, Ashby, 1925.

Genus PROTOLORICA Ashby, 1925.
Protolorica atkinsoni Ashby, 1925.

Genus LORICELLA Pilsbry, 1893.

Loricella gigantea Ashby and Torr, 1901.
L. paucipustulosa Ashby and Torr, 1901.
Subgenus PSEUDOLORICELLA Ashby, 1925.
Loricella (Pseudoloricella) sculpta Ashby, 1921.

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EXPLANATION OF PLATE XXIV.

Fig. 1.—*Oöchiton halli*, n. sp. Balcombe Bay, Vic.; Balcombian. Holotype, median valve. (*a*) side view, ornamentation and broken insertion plate, × 7; (*b*) upper side, × 7. Nat. Mus. No. 13496.

Fig. 2.—*O. halli*, n. sp. Belmont, Vic.; Balcombian. Paratype, median valve, showing ornamentation and complete insertion plate, × 6·5. Nat. Mus., No. 13497.

Fig. 3.—*O. halli*, n. sp. Balcombe Bay, Vic.; Balcombian. Paratype, taken as type of tail valve. (*a*) posterior of valve tilted upwards, to show truncated posterior, also ornamentation, × 6·5; (*b*) side view, showing complete insertion plate, slit and truncated posterior, × 7. Nat. Mus. No. 13494.

Fig. 4.—*Notochiton mirandus* Thiele. Antarctica, dredged: Recent. Cotype, anterior valve, side view showing insertion plate and sculpture for comparison with *Oöchiton halli*, × 5. Ashby Coll.

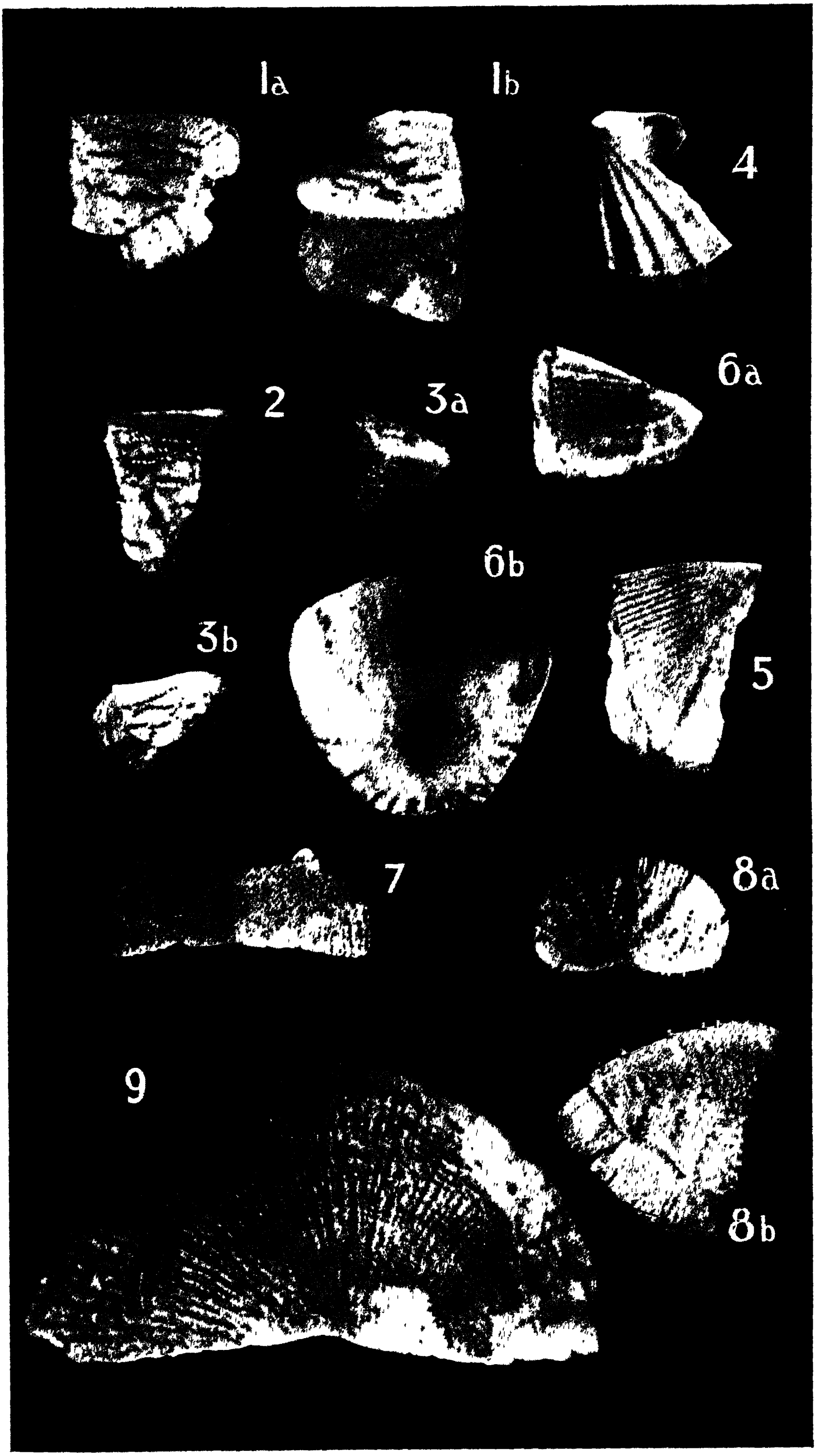
Fig. 5.—*N. mirandus* Thiele. Median valve, side view. × 5. Ashby Coll.

Fig. 6.—*N. mirandus* Thiele. Tail valve. (*a*) side view showing sculpture, mucro and insertion plate, × 5; (*b*) same valve, inside, showing teeth, × 7. Ashby Coll.

Fig. 7.—*Ischnochiton (Heterozona) cariosus* Pilsbry. Balcombe Bay; Balcombian. Median valve, × 7.

Fig. 8.—*Oöchiton halli*. Ashby. Balcombe Bay; Balcombian. Paratype, here taken as type of anterior valve. (*a*) showing sculpture and insertion plate, × 6; (*b*) side view, showing anterior slope, sculpture and insertion plate, × 12. Ashby Coll.

Fig. 9.—*Loricella gigantea*. Ashby and Torr. Table Cape, Tas., Lower Bed; Janjukian. Anterior valve showing shape and sculpture, × 3·5. Nat. Mus. No. 13499.



E Ashby, photo,

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Piesse, E. L., 43 Sackville-street, Kew, E.4 1921
Pratt, Ambrose, M.A., 376 Flinders-lane, Melbourne, C.1 1918

Quayle, E. T., B.A., 27 Collins-street, Essendon, W.5 .. 1920

Rae, F. J., B.Sc., B.Ag.Sc., Botanic Gardens, South Yarra, S.E.1. 1927
Reid, J. S., 498 Punt-road, South Yarra, S.E.1 1924
Rivett, Dr. A. C. D., M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2. 1911
Rogers, J. Stanley, B.A., M.Sc., University, Carlton, N.3 . 1924
Ryan, Rev. Wilfrid, S.J., M.A., F.G.S., Newman College, Carlton, N.3. 1926

Schlapp, H. H., 31 Queen-street, Melbourne, C.1 1906
Shephard, John, " Norwood," South-road, Brighton Beach, S.5. 1894
Shillinglaw, Godfrey V., 64 Dandenong-road, Caulfield, S.E.7. 1925
Singleton, F. A., M.Sc., University, Carlton, N.3 1917
Skeats, Prof. E. W., D.Sc., A.R.C.Sc, F.G.S., University, Carlton, N.3. 1905
Smith, B. A, M.C.E., Mutual Building, 395 Collins-street, Melbourne, C.1. 1924
Spencer, Prof. Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S., National Museum, Melbourne, C.1. 1887
Stillwell, F. L., D.Sc., 44 Elphin-grove, Hawthorn, E.2 .. 1910
Summers, Associate Prof. H. S., D.Sc., University, Carlton, N.3. 1902

Sweet, Georgina, D.Sc., Cliveden Mansions, Wellington-parade, East Melbourne, C.2. 1906

Thirkell, Geo. Lancelot, B.Sc., 4 Grace-street, Malvern, S.E.4. 1922
Thomas, Dr. D. J., M.D., 12 Collins-street, Melbourne, C.1. 1924
Tiegs, O. W., D.Sc., University, Carlton, N.3. 1925
Trinder, E. E., M.I.H.V.E., "Ruzilma," Orrong-grove, Caulfield, S.E.7. 1922

Wadham, Prof. S. M., M.A., Agr.Dip., University, Carlton, N.3. 1927
Walcott, R. H., Technological Museum, Melbourne, C.1 .. 1897
Weber, E. K., 49 Armadale-street, Armadale, S.E.3 1927
Wickens, C. H., F.I.A., F.S.S., Commonwealth Statistician, Canberra, F.C.T. 1923
Woodruff, Prof. H. A., M.R.C.S., L.R.C.P., M.R.C.V.S., Veterinary School, Parkville, N.2. 1913

Young, Assoc. Prof. W. J., D.Sc., University, Carlton, N.3 1923

Country Members.

Caddy, Dr. Arnold, "Chandpara," Tylden, Vic. 1924
Crawford, W., Gisborne, Vic. 1920

Drevermann, A. C., Dookie Agricultural College, Dookie, Vic. 1914

Easton, J. G., "Kiewa," Murphy-street, Bairnsdale, Vic. 1913

Harris, W. J., B.A., High School, Echuca, Vic. 1914
Hart, T. S., M.A., B.C.E., School of Mines, Bairnsdale, Vic. 1894
Hope, G. B., B.M.E., "Carrical," Hermitage-road, Newtown, Geelong, Vic. 1918

James, A., B.A., M.Sc., High School, Colac, Vic. 1917

Kitson, Sir Albert E., C.M.G., C.B.E., F.G.S., 75 Cornwall Gardens, Kensington, London, S.W.7, England. 1894

Langford, W. G., M.Sc., B.M.E., "Vailala," Elizabeth-street, Gordon, Sydney, N.S.W. 1918
Lea, A. M., F.E.S., 241 Young-street, N. Unley, S. Aus. 1909

Mackenzie, H. P., Engr. Commr. R.N.(Ret.), Trawalla, Vic. 1924

Parker, L. C., B.Sc., High School, Ballarat 1927

Sutton, J. W., 127 Doncaster-avenue, Kensington, Sydney, N.S.W. 1924

Trebilcock, Captain R. E., M.C., Wellington-street, Kerang, Vic. 1921

White, R. A., B.Sc., School of Mines, Bendigo, Vic. 1918

Corresponding Member.

Lucas, A. H. S., M.A., B.Sc., Sydney Grammar School, Sydney, N.S.W. 1895

Associates.

Albiston, H. E., M.V.Sc., Veterinary School, Parkville, N.2. 1925
Allen, J. M., M.A., 41 Nirvana-avenue, East Malvern. S.E.5. 1924
Allen, Miss N. C. B., B.Sc., University, Carlton, N.3 1918
Archer, Howard R., B.Sc., c/o J. M. Moffatt, Faulkner-street, Armidale, N.S.W. 1921
Ashton, H., "The Sun," Castlereagh-street, Sydney, N.S.W. 1911

Bage, Mrs. Edward, "Cranford," 7 Gellibrand-street, Kew, E.4. 1906
Bage, Miss F., M.Sc., Women's College, Kangaroo Point, Brisbane, Qld. 1906
Baker, F. H., 167 Hoddle-street, Richmond, E.1 1911
Barkley, H., Meteorological Bureau, Melbourne, N.3. .. 1910
Barnard, R. J. A., M.A., University, Carlton, N.3 1926
Bordeaux, E. F. J., G.M.V.C., B. ès L., Mangalore-street, Flemington, W.2. 1913
Breidahl, H., M.Sc., M.B., B.S., 23 Chatsworth-avenue, North Brighton, S.5. 1911
Brodribb, N. K. S., Ordnance Factories, Maribyrnong, W.3. 1911
Buchanan, Gwynneth, D.Sc., University, Carlton, N.3 1921

Carter, A. A. C., "Fairholm," Threadneedle-street, Balwyn, E.8. 1927
Chapman, W. D., M.C.E., "Hellas," Heidelberg-road, Clifton Hill, N.8. 1927
Chapple, Rev. E. H., The Manse, Warrigal-road, Oakleigh, S.E.12. 1919
Cherry, R. O., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927
Clinton, H. F., Produce Office, 605 Flinders-street, Melbourne, C.1. 1920
Collins, A. C., Public Works Department, Treasury Gardens, Melbourne, C.2. 1928
Cook, G. A., M.Sc., B.M.E., 18 Elphin-grove, Hawthorn, E.2. 1919

Cookson, Miss I. C., B.Sc., 154 Power-street, Hawthorn, E.2. 1916
Coulson, A. L., M.Sc., D.I.C., F.G.S., "Finchley," King-street, Elsternwick, S.4. 1919
Cox, E. H., Literary Staff, "The Argus," Elizabeth-street, Melbourne, C.1. 1924
Crespin, Miss I., B.A., 67 Studley Park-road, Kew, E.4 .. 1919

Dare, J. H., B.Sc., State School, Brunswick, N.10 1917
Deane, Cedric, "Cloyne," State-street, Malvern, S.E.4 .. 1923

Feely, J. A., Observatory, South Yarra, S.E.1 1924
Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A. 1913
Ferguson, W. H., 37 Brinsley-road, E. Camberwell, E.6 .. 1894
Finney, J. M., 36 Toorak-road, Malvern, S.E.4 1925
Flecker, Dr. H., 71 Collins-street, Melbourne, C.1 1922

Gabriel, C. J., 293 Victoria-street, Abbotsford, N.9 1908

Hardy, A. D., F.L.S., Forests Department, Melbourne, C.2. 1903
Hartung, Prof. E. J., D.Sc., University, Carlton, N.3. 1923
Hauser, H. B., M.Sc., Geology School, University, Carlton, N.3. 1919
Hercus, E. O., D.Sc., A.Inst.P., University, Carlton, N.3 1923
Heslop, G. G., D.V.Sc., 7 Hudson-street, Caulfield, S.E.7. 1923
Hill, Gerald F., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2. 1924
Hills, E. S., B.Sc., Geology School, University, Carlton, N.3. 1928
Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1. 1913
Howitt, A. M., Department of Mines, Melbourne, C.2 ... 1910

Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1. 1927
Jona, J. Leon, M.D., B.S., D.Sc., "Hazelmere," 104 Wattle Tree-road, Malvern, S.E.4. 1914

Kannuluik, W. G., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927
Keartland, Miss B., M.Sc., Cramer-street, Preston, N.18 1919
Keble, R. A., National Museum, Melbourne, C.1 1911

Lambert, C. A., Bank of N.S.W., Melbourne, C.1 1919
Lambert, J. R., 135 Drummond-street, Carlton, N.3 1928
Leslie, J. R., 99 Toorak-road, South Yarra, S.E.1 1923
Lewis, Miss R. M., 52 Campbell-road, East Kew, E.4 1925

Llewelyn, Miss Sybil, M.A., M.Sc., St. Quentin, Broadway, Elwood, S.3. 1928
Luly, W. H., Department of Lands, Public Offices, Melbourne, C.2. 1896

Macdonald, B. E., Dairy Export Branch, Rialto, Collins-street, Melbourne, C.1. 1920
Mackenzie, G., 1 High-street, Prahran, S.1 1907
Maclean, C. W., 56 Cole-street, Elsternwick, S.4 1879
McLennan, Ethel, D.Sc., University, Carlton, N.3. .. 1915
Melhuish, T. D'A., M.Sc., Adelaide Chemical and Fertilizer Co., Currie-street, Adelaide, S.A. 1919
Mollison, Miss E., M.Sc., Royal-crescent, Camberwell, E.6. 1915
Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, Melbourne, C.2. 1920
Morris, P. F., National Herbarium, South Yarra, S.E.1. .. 1922

Nelson, Miss E. A., M.A., M.Sc., University, Carlton, N.3 1924
Newman, B. W., Meteorological Offices, Melbourne, C.1 1927

Oke, C., 56 Chaucer-street, St. Kilda, S.2 1922
Orr, D., B.Sc., 860 Mount Alexander-road, Essendon, W.5 1927

Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8 1927
Pern, Dr. Sydney, M.R.C.S., L.R.C.P., 16 Collins-street, Melbourne, C.1. 1920
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2. 1919
Pretty, R. B., M.Sc., Technical School, Warrnambool, Vic. 1922

Raff, Miss J. W., M.Sc., F.E.S., University, Carlton, N.3 1910
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11 1923
Rosenthal, Newman, H., B.A., B.Sc., 11 Wimbledon-ave., Elwood, S.3. 1921
Ross, Miss D. J., M.Sc., Merton Hall, Anderson-street, South Yarra, S.E.1. 1924

Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3. 1924
Sharman, P. J., M.Sc., "Glenalvie," 9 Daphne-street, Canterbury, E.7. 1916
Shearer, J., B.Sc., Queen's College, Carlton, N.3 1924
Sherrard, Mrs. H. M., M.Sc., "Balnagowan," Bromley-ave., Cremorne, N.S.W. 1918
Shiels, D. O., M.Sc., Ph.D., Chemistry School, University, Carlton, N.3. 1927
Simpson, H. W. C., 64 Dandenong-road, Caulfield North, S.E.7. 1927

Smith, J. A., 25 Collins-place, Melbourne, C.1 1905
Stickland, John, 433 Brunswick-street, Fitzroy, N.6. 1922
Sutton, C. S., M.B., B.S., Education Department, Melbourne, C.2. 1908

Thomas, R. G., B.Ag.Sc., c/o Dr. Thomas, Northam, W.A. 1922
Thompson, Mrs. G. R., 26 Fawkner-street, St. Kilda, S.2 1922
Thorn, Wm., 37 Chrystobel-crescent, Hawthorn, E.2 1907
Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3. 1903
Treloar, H. M., Meteorological Offices, Melbourne, C.1 .. 1922
Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9 .. 1918
Turner, A. H., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927
Turner, A. W., M.V.Sc., Veterinary School, Parkville, N.2. 1925

Wilcock, E. L., B.Sc., University High School, Carlton, N.3. 1925
Williamson, H. B., F.L.S., "The Grange," 231 Waverley-road, East Malvern, S.E.5. 1919
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5. 1921
Wilson, Major H. W., O.B.E., M.C., C.de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7. 1923
Withers, R. B., 10 Nicholson-street, Coburg, N.13. 1926
Woodward, J. H., Queen's Buildings, 1 Rathdown-street, Carlton, N.3. 1903

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The names of the new genera and species are printed in italics.

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PROCEEDINGS

OF THE

Royal Society of Victoria.

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(Containing Papers read before the Society during the months of April to December, 1929.

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VICTORIA STREET, MELBOURNE, C. 1.

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CORRIGENDA.

Volume XL.

Page 8, line 11, for "CUNNINGHAMI" read "CUNNINGHAMII".
" 92, " 25, for "Plate X." read "Plate IX."

Volume XLI.

Page 7, line 14, for "5 cm." read "5 mm."
" 10, lines 6 and 7, the words "a split external ectodermal lamella, according to Kuhn" should be in parentheses.
" 20, line 4, delete whole line.
" 25, " 39, for "ACANTHOSTOMA" read "ACANTHOCARPA."
" 55, " 35, for "vaccum" read "vacuum."
" 121, " 7, for "November" read "October".
" 176, " 26, for "Anglesea" read "Anglesey".
" 178, " 8, for "western" read "eastern".
" 185, " 22, for "Newberry, 1889" read "(Claypole, 1883)"
" 197, " 18, for "Fig. 2, No. 6" read "Fig. 2, No. 4."
" 197, " 27, for "Newberry, 1889" read "(Claypole, 1883)"
" 199, " 5, for "1914" read "1915"
" 199, " 25, for "113-127" read "67-146."

ADDENDA.

Volume XLI.

Page 179, after line 5 add "Pelecypoda. *Nuculites* cf. *maccoyianus* Chapm."
" 198, after line 36 add "CLAYPOLE, E.W., 1883. *Proc. Amer. Phil. Soc.*, xx., p. 664."

CONTENTS OF VOLUME XLII., PART I.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. I., 1929.]

ART. I.—*A List of Australian Sea-grasses.*

By C. H. OSTENFELD.

(Copenhagen, Denmark.)

(Communicated by Professor A. J. Ewart.)

[Read 11th April, 1929: issued separately 9th October, 1929.]

The sea-grasses of a flora are often somewhat neglected, as owing to their peculiar habitat they usually are not collected by plant collectors working on land. On the other hand students of marine Algae also omit to collect them, as not belonging to their special sphere of interest.

A study of the geographical distribution of these interesting spermatophytes has led me to examine the material of sea-grasses preserved in different larger herbaria of the world. My own voyages have added to the knowledge of the occurrence the world over of these plants, and in a preliminary paper (1) I have sketched some of my results, and quite recently I have published a series of maps showing the outlines of their distribution (2).

As to the sea-grasses of Australia a detailed study of the West Australian ones, based upon my own collections in 1914, has augmented their number in that part of Australia (3), and by the examination of the National Herbaria of New South Wales (Sydney), and Victoria (Melbourne), and some recent collections from the Eastern States, I discovered several further interesting additions to our knowledge of the distribution of the sea-grass Flora of Australia.

I think it, therefore, worth while to give a short enumeration of the species of sea-grasses of Australia, and the localities of the specimens seen by me.

I am not, at present, able to give a definite opinion as regard the specific value of the Zosteras of Australia, and prefer, preliminarily, to refer them all to two species—*Z. Mülleri* Irmisch, and *Z. capricorni* Aschers.

I do not quote the records given in the floras (Bentham, Flora Austr., vii.; F. v. Müller, Sec. Census Austr. Pl.), but mention only the specimens actually seen.

As regard to the synonymy, I refer to P. Ascherson in Das Pflanzenreich, iv., 2, 1907.

Fam. POTAMOGETONACEAE.

Cymodocea.

1. *C. angustata* Ostf.—Western Australia: Carnarvon (Herb. Copenh.).

2. *C. antarctica* (Labill.) Endl.—R. Brown, Iter Austr. No. 5814 (Brit. Mus.). Victoria: south coast, Tasmania, South Australia, and Western Australia, as far north as Geraldton.
3. *C. ciliata* (Forsk.) Ehbg.—Queensland: near Port Denison (Herb. Melb.), Queensland shores (Kew).
4. *C. isoctifolia* Aschers.—Queensland: Edgecombe Bay (Kew); Port Denison, Fitzalan (Herb. Melb.).
   Western Australia: Champion Bay (Herb. Melb.; Lund Herb.); Geraldton and Carnarvon (Herb. Copenh.).
5. *C. rotundata ?* (Ehrbg., Hempr.), Aschers and Schweinf. —Queensland: Port Denison, Fitzalan (Herb. Melb.). The identification of this fragmentary material is not quite certain. Reported from NW. Australia, floating near the Montebello Islands (Ascherson) ?; perhaps *C. angustata.*
6. *C. serrulata* (R.Br.), Aschers. and Magn.—R. Brown, Iter Austr. No. 5813 (Brit. Mus.).
   Queensland: Port Denison (Kew).

Diplanthera.

7. *D. uninervis* (Forsk.) Aschers.—Queensland: Port Denison (Fitzalan) and Rockingham Bay, 1883, F v. Müller (Herb. Melb., Herb. Copenh.); Pialba, 1921, Sab. Helms (Herb. Copenh.).

Posidonia.

8. *P. australis* Hook fil.—R. Brown, Iter Austr. Nos. 5812 and 5817 (Brit. Mus.). South coast of the continent, many places. Tasmania, Western Australia, as far north as Carnarvon (Herb. Copenh.).

Zostera.

9. *Z. capricorni* Aschers.—Queensland: Cape York (Herb. Kew).
   New South Wales: Sydney Harbour, 1915, Th. Mortensen (Herb. Copenh.); Long Reef, north of Port Jackson, 1914, Th. Mortensen (Herb. Copenh.); Botany Bay, Sans Souci, 1915 and 1917, Boorman (Herb. Copenh.); Harwood Island, Clarence River, 1922, Sab. Helms (Herb. Copenh.).
10. *Z. Mülleri* Irmisch.—Victoria: Austr. Felix, F. v. Müller 1852 (Herb. Melb.); Port Phillip Heads (Brit. Mus.; Herb. Copenh.); Point Lonsdale, Josephine Tilden (U.S. Nat. Herb.).
   South Australia: Mouth of Hindmarsh River, Victor Harbour, 1928, J. B. Cleland (Herb. Copenh.); Ade-

laide, Victor Harbour, 1914, W. Herdman (Herb. Copenh.); Port Pirie, 1914, Gunnar Andersson (Herb. Copenh.).

Tasmania: *sine loco,* J. R. Gunn (Herb. Sydney; Herb. Copenh.); Tasman Penins., Port Arthur, 1914, L. S. Gibbs (Herb. Copenh.); D'Entrecasteaux Channel, Port Esperance and South Port, 1915, L. S. Gibbs (Herb. Copenh.).

Fam. HYDROCHARITACEAE.

Halophila.

11. *H. decipiens* Ostf.—New South Wales: Sydney Harbour, Brazier and Ramsay, 1884 (Herb. Sydney).
   Queensland: Pialba, 1921, Sab. Helms (Herb. Copenh.).
12. *H. ovalis* (R.Br.) Hook, fil.—R. Brown, Iter Austr., No. 5816 (Brit. Mus.; Kew).
   Queensland: Pialba, 1921, Sab. Helms (Herb. Copenh.); Port Denison (Upsala Herb.); Cape York (Brit. Mus., Kew).
   New South Wales: Port Jackson (Herb. Sydney).
   Lord Howe Island: MacDonald, 1855 (British Mus.; Kew Herb.).
   Victoria: Western Port Bay (Brit. Mus.; Hamburg Herb.); Sorrento (Lund Herb.); Port Phillip (Berlin Herb.; Kew; Herb. Melb.).
   Tasmania: Georgetown, J. R. Gunn (Kew Herb.; Herb. Bremen; Herb. Copenh.).
   West Australia: Rottnest Island and Freshwater Bay, Swan River (Brit. Mus.; Kew); Yallingup and Geraldton, 1914 (Herb. Copenh.).
13. *H. spinulosa* (R.Br.) Aschers.—R. Brown, Iter Austr., No. 5815 (Brit. Mus.).
   Queensland: Port Denison (Herb. Melb.; Herb. Calcutta; Herb. Acad. Leningrad); Pialba, 1921, Sab. Helms (Herb. Copenh.); Cape York (Kew); Albany Is. in Moreton Bay (Kew); Brisbane (Kew).

Thalassia.

14. *T. Hemprichii* (Ehrbg.) Aschers.—Queensland; Port Denison, Fitzalan (Herb. Melb.); Murray Is., Torres Strait, C. Hedley, 1907 (Herb. Sydney, sub. nom. *Cym. ciliata,* cfr. J. H. Maiden and E. Betche, *Proc. Linn. Soc. N.S.W.,* December, 1909).

Enhalus.

15. *E. acoroides* (L. fil.) Steud.—Queensland: Thursday Is., J. Douglas, 1886 (Herb. Melb.); Cape York, Challenger Exp., 1874 (Kew).

As stated above, the list contains only the localities from which I have seen specimens. No doubt the distribution of the different species along the coasts of Australia will be extended by future investigations, and I shall with pleasure identify any specimen of sea-grass sent to me, and hope that collectors will help me by sending me unnamed specimens. It is possible to name the species also from sterile specimens, but of course it is more interesting to get some with flowers and fruits. Of some of the species I have only seen sterile specimens from Australia, e.g., *Halophila ovalis, Cymodocea serrulata* and *C. ciliata.*

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[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. I., 1929.]

ART. II.—*An Account of a Crown Rot of English Walnut Trees in Victoria.*

By ISABEL C. COOKSON, B.Sc.
(Research Scholar in the University of Melbourne).

(With Plate I.)

[Read 11th April, 1929; issued separately 9th October, 1929.]

Introduction.

A crown Canker or Root Rot disease of the Black Walnut (*Juglans Hindsii* Jepson) growing in Northern California became evident during the spring of 1922. R. E. and E. H. Smith (21), in a study of the disease, isolated a fungus which, on account of its cultural characteristics and the nature of its reproductive organs, was compared by them to *Phytophthora cactorum* (Cohn and Lebert) Schroeter.

A root disease of the English walnut (*J. regia* Linn.) has been established in the Bright district of Victoria for some years, of which one of the first symptoms is the occurrence of irregular black areas on the surface of the trunk, at, or just below, the level of the soil. Such regions ring hollow when knocked, and in them the dead bark is readily removed from the underlying wood cylinder. A quantity of a dark watery fluid may collect in a space formed by the separation of the stem tissues in the cambial zone, or this liquid may exude through cracks and appear on the surface as dark, gummy drops.

The leaves of a tree showing such symptoms will usually appear yellowish in colour, will fall early, and in time the whole tree will succumb to the effects of the disease.

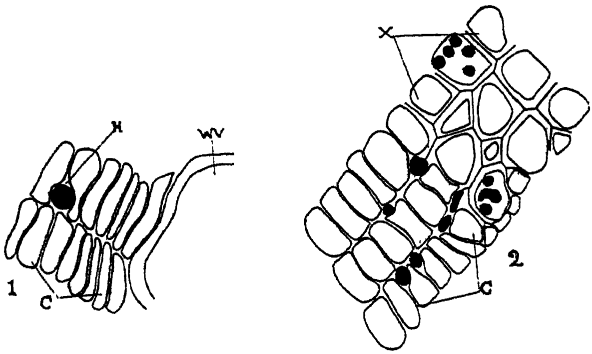
If the root system of a diseased tree be carefully examined, it will be found that many of the roots, of all sizes (those examined ranging from 7·5 cm.-1·5 cm. diam.), may be distinguished by the presence of irregular areas in which the bark has undergone a dark-brown discoloration, accompanied by the exudation of the brown liquid, as previously seen on the surface of the trunk. The darkening extends inwards as far as the wood, and involves a strip of the sap wood about 2 mm. wide. In later stages, here as in the stem, an almost complete separation takes place at the junction of the wood and the phloem, with the result that the bark is easily removed from the underlying wood cylinder. The discoloration is strictly limited, and usually includes only a small amount of the circumference of the root. In no case has an

entire girdling of the root been observed, although the presence of several darkened patches separated by healthy uncoloured bark is quite usual.

The Diseased Tissues.

Microscopic examination of the diseased areas has revealed in them the presence of non-septate fungal hyphae. These are clearly demonstrated in hand sections of the root which have been cleared in Lacto-Phenol solution, stained in 0·3% Cotton Blue in Lacto-Phenol and finally mounted in Lacto-Phenol according to the method adopted by Cook (7).

The hyphae of the invading fungus are only evident in the discoloured regions, none being present in the adjoining healthy tissues. The fungus is most abundantly found in the secondary phloem, adjacent to the cambial zone, where its hyphae occupy the intercellular spaces, and make their way between the cell walls of neighbouring cells. In the cambial region, intercellular

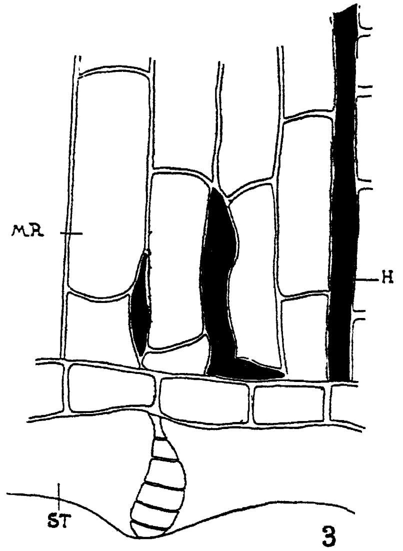


FIGS. 1 and 2.—Transverse sections at junction between the cambium and wood, showing intra and intercellular hyphae. ×280.
h. hyphae; c. cambium; w v. wood vessel; x. xylem

hyphae occur abundantly (Fig. 2). The outer cortex of the root is usually free from infection, but hyphae have been observed between the starch-containing cells of the inner cortex. In the cortex, phloem and cambium, the general direction of growth is longitudinal, although many of the isodiametric, storage phloem and cortical parenchymatous cells are almost completely surrounded by branching hyphae. In the medullary rays, the very conspicuous and numerous hyphae follow a radial, intercellular course (Fig. 3); they can be traced both in transverse and radial longitudinal sections for considerable distances between the ray cells. In their passage in the radial direction they give off branches at intervals which, later, may themselves travel in the direction of the parent hypha.

A small strip of the youngest wood, though usually involved in the discoloration produced by the presence of the fungus, is

often free from fungal invasion. Occasionally, however, the hyphae enter both the young wood vessels and wood fibres, and in them pursue an intracellular and longitudinal course (Figs. 2 and 4). The hyphae, which branch freely and anastomose in the cavities of the fibres and vessels, have not been observed either in or



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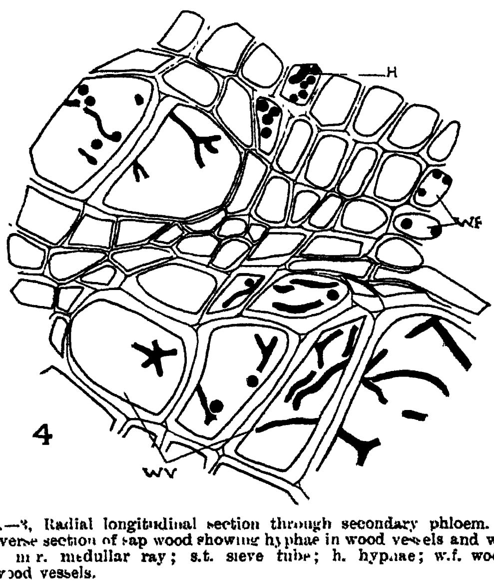

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FIGS 3 and 4.—3, Radial longitudinal section through secondary phloem. ×400. 4, Transverse section of sap wood showing hyphae in wood vessels and wood fibres ×280. m.r. medullar ray; s.t. sieve tube; h. hyphae; w.f. wood fibres; w.v. wood vessels.

between the wood parenchyma cells. An entrance to the wood fibres and vessels is obtained by means of the bordered pits on their walls. The penetrating hypha undergoes considerable diminution in size as it enters the mouth of the pit, then becomes slightly enlarged in the region of the original middle lamella which has been dissolved during its passage, and finally narrows again as it leaves the pit to enter the cavity (Fig. 5).

The spread of the fungus in both a tangential and longitudinal direction appears to be limited by the very frequent development of cork tissue at the junction of the stained and unstained areas of the root. This self-limitation has been noted previously by Fawcett (11) in his study of "Pythiacystis Gummosis," and by Dufrenoy (9) during his investigations on the fungi causing "gummosis" of Citrus trees.

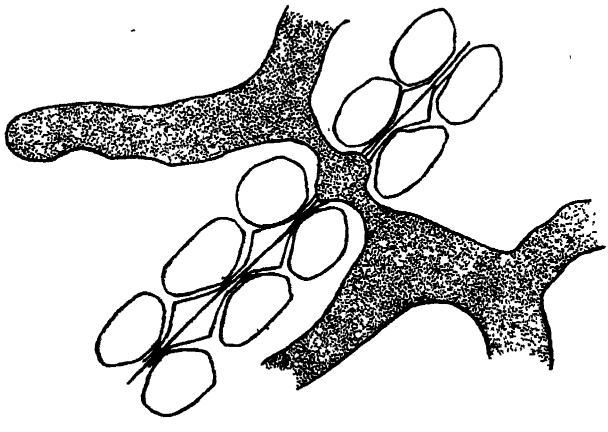

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FIG. 5.—The wood in longitudinal section showing the passage of hypha from one vessel to another. ×1000.

The mode of entry of the parasite into the host has not yet been determined. Its presence has been demonstrated in a small lateral rootlet 2 mm. in diameter, arising from a diseased root of 1·5 cm. diameter. There was no indication, however, in the example studied to suggest in which direction the fungus was travelling. No haustoria have been seen, and only the vegetative stage of the fungus has been met within the infected tissues of the walnut root.

The Fungus in Culture.

Many attempts to isolate the fungus in pure culture were unsuccessful. The method adopted was to remove with a sterilized razor the outermost layers of the bark, where saprophytic fungi were likely to be most abundant, and then to cut longitudinal sections of the tissue at the junction of wood and bark, including,

wherever possible, a portion of both the stained and healthy regions of the root. The sections thus obtained were placed in sterilized water, from which they were transferred to plates of 3% malt agar. One such culture, though bacterially contaminated, on 17th October, 1927, after five days at room temperature, showed a phycomycetous growth from the section of root tissue. A sub-culture was made on plain agar, from which it was possible to obtain pure cultures.

The fungus isolated grows readily on most of the media in general use, producing both a submerged and an aerial growth. The aerial mycelium is most abundantly developed on maize-meal, haricot bean, and oatmeal agar, and when young is composed of regular, sparingly-branched, thin-walled, non-septate hyphae, rich in granular protoplasm, and oil drops. Later, frequent septations occur, as well as a general thickening of the cell wall. This thickening, which is also met with in the submerged mycelium, is most evident in maize-meal cultures after a period of three weeks, when it occurs to such an extent as almost to obliterate the cavities of the filaments.

The submerged hyphae are uniform in diameter on oat agar, but in such media as malt agar, potato-dextrose agar, bean meal agar, and prune juice, become more or less irregularly swollen and gnarled (Fig. 6). With age, the finely granular hyphal contents are replaced by large drops of oil, which occur along the length of the hyphae.

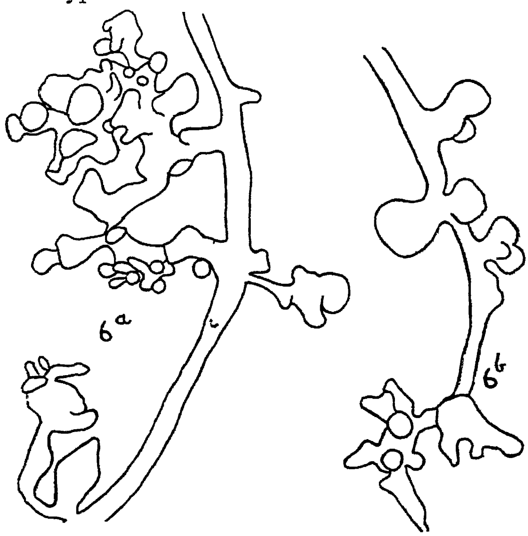
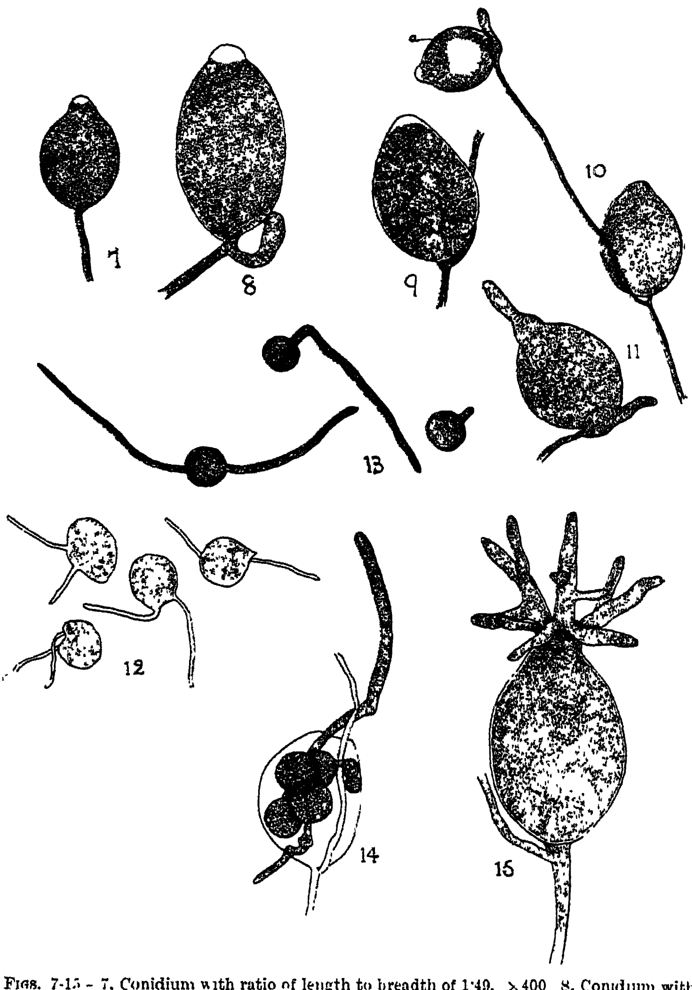


FIG. 6.—*a*, Submerged hyphae from malt agar culture; *b*, Similar hyphae from potato-dextrose agar culture. Both ×400.

Conidia of the type characteristic of the genus *Phytophthora* have been developed when cultures of the fungus were made on

damp sterilized soil. The method adopted has been to obtain an active culture, by three or four days' growth in prune juice, which could then be transferred directly to a petri dish containing moist sterilized soil. After a week or longer, conidia were developed, though never in large numbers.

The conidia are ovate, occasionally elliptical, papillate, arising terminally on long unbranched conidiophores. The latter may



FIGS. 7-15 – 7, Conidium with ratio of length to breadth of 1·49. ×400. 8, Conidium with ratio of length to breadth of 1·95. ×400. 9, Conidium from soil agar culture after a period of two hours in water. ×400. 10, Conidiophore from soil-agar culture ×280. 11, Conidium 10*a* after 5 hours in water, germinating directly. ×400. 12, Zoospores killed with iodine. ×400. 13, Zoospores which have rounded off, germinating. ×400. 14, Conidium 6 hours after the escape of zoospores, showing the germination of unliberated zoospores in situ. ×400. 15, Conidium from 11 days' soil-culture, after 7 hours in water, showing the direct type of germination. ×400.

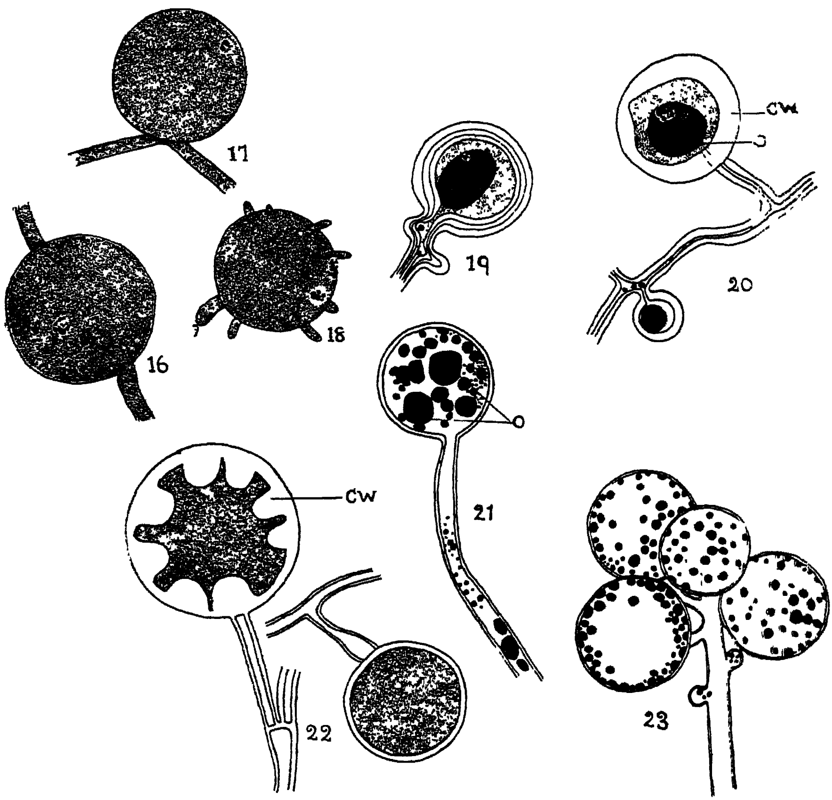
undergo further growth by which the conidium is pushed slightly to one side on a short pedicil, a sympodial arrangement thus being established (Figs. 8, 9, 10). The attachment of the conidium is always basal, no instance of a lateral position having been observed. The conidia vary very considerably both in size and shape, ranging from 30-82·5 μ in length, and 19·5-49·5 μ in breadth, the ratio of width to length varying from 1·11-2·00; while the average length of 114 conidia was 55·9μ, the average width of 114 conidia 36·6 μ and the ratio of length to width of 114 conidia was 1·50.

The germination of the conidium is readily observed by transferring portion of the mycelium to a drop of water on a glass slide. When immersed in a film of water, after a period of one to two hours at room temperature a variable number of zoospores are liberated. The conidium at first contains finely granular protoplasm (Figs. 7 and 8), but this soon is faintly delimited and the outlines of the individual zoospores become evident (Fig. 9). Just before maturity, a slight movement takes place in the contents of the conidium, after which the papilla gradually enlarges, being inflated as if by pressure from within. Meanwhile, some of the protoplasm flows into the papilla, the individuality of the zoospores appearing to be somewhat lost during the process. The papilla then bursts, and the zoospores separate from one another and rapidly swim away. The spores which have remained in the conidium now squeeze their way through the narrow opening of the sporangium, becoming dumbbell-shaped in the passage, and escape one by one. The zoospores are fusoid, biciliate bodies, and appear to be longitudinally grooved. Two vacuoles are usually present, and the cilia are generally of unequal length (Fig. 12). After a period of activity the zoospore settles down, rounds itself off, and germinates by means of one, or occasionally two, germ tubes (Fig. 13). The zoospore when rounded off and at rest has a diameter of from 12-13·5μ. The whole process from the time that the conidium was first observed to the time when the germ tube was quite evident was accomplished within eight hours on a cool day at room temperature.

Very often, one to several of the zoospores fail to leave the sporangium in spite of the activity of their movements and their close proximity to the exit point. These eventually become rounded off within the conidium and germinate there in situ, the germ tubes piercing the wall or else passing to the exterior through the papilla opening (Fig. 14).

If suitable conditions for zoospore formation do not obtain, the finely granular protoplasm of the conidium remains undivided, and one to several germ tubes arise from the region of the papilla, either as the direct outgrowth from this enlarged structure, or from the wall of the conidium around the papilla (Fig. 15).

Chlamydospores, or the "Resting Conidia" of Dastur (8), are the most characteristic organs met with in cultures of this fungus. Whereas the conidia are only produced when the fungus is grown on damp soil or soil agar, chlamydospores are abundantly developed on all the solid culture media used during this investigation. They occur on both the aerial and immersed mycelia, though most abundant in the subaerial and submerged portions of the growth. A typical chlamydospore is a spherical body borne either terminally, laterally, or intercalarly on a hypha (Figs. 16, 17, 22, 23). At first the cell wall is thin, and the contents are finely granular, only the shape and absence of a papilla distinguishing them from conidia (Figs. 17, 18). Later, the wall may



FIGS. 16-23.—16 and 17, Intercalary chlamydospores from a soil culture. ×400 18, Chlamydospore germinating after 9 hours in water at room temperature. ×400. 19, Thick-walled chlamydospore from 23 weeks' culture on maize-meal agar, showing successive deposition of cellulose layers. ×400. 20, Submerged mycelium with thick-walled chlamydospore from 20 weeks' culture on maize-meal agar ×400. 21, Terminal chlamydospore on submerged mycelium of maize-meal culture. ×400. 22, Thick walled clamydospores from submerged mycelium of bean-meal culture. ×400. 23, A cluster of chamydospores from submerged mycelium of 6 weeks' potato-dextrose agar cufture. ×400. c.w. thickened cell-wall; o. oil globules

become thickened by the deposition of layers of cellulose, as seen by the action of phosphoric acid and iodine, the degree of thickening depending both on the nature of the culture medium, and the age of the culture. On maize-meal agar, a maximum of thickening takes place; in some cases, especially in submerged chlamydospores, the diameter of the wall may measure as much as 9μ, when the cavity of the organ is almost obliterated, only a thin basal canal then connecting the reduced cavity with that of the supporting hypha (Figs. 19, 20). The successive layers of cell wall substance are clearly marked, and the width of the wall is even around its whole circumference (Fig. 19).

On bean-meal agar, many of the chlamydospores also become very thick-walled, but in this case the thickening is laid down in circular areas which project as blunt processes into the cavity of the spore. (Fig. 22).

In oatmeal, malt, and potato dextrose agars, though thickening of the vegetative hyphae may occur, the walls of the majority of chlamydospores are only slightly thickened.

All chlamydospores begin as thin-walled structures, and whether or not thickening of the wall takes place depends on external conditions. Their contents are dense, and at first finely granular, and this gives the appearance of slight coloration under a low magnification; but under a high power it is clearly evident that they are quite hyaline in character. This feature persists, for even in extreme age no yellowing is discernible. A central vacuole may sometimes be present. Later, small, regular globules which give a positive reaction with Sudan III fill the cavity of the spore, and in old specimens, especially the very thick-walled ones previously referred to, these run together to form fewer and larger oil globules (Figs. 20, 21, 23). Many of the chlamydospores in culture appear as empty sacs, devoid of contents, of which they have been drained apparently to supply a demand elsewhere.

Spherical chlamydospores are the most typical in form, but oval and irregular shapes are far from uncommon on the aerial and submerged mycelia. Their variation in diameter, however, is much greater, and in 225 spherical examples measured, ranged from $13 \cdot 5$ to $64 \cdot 5\mu$ with a mean of $35 \cdot 96\mu$.

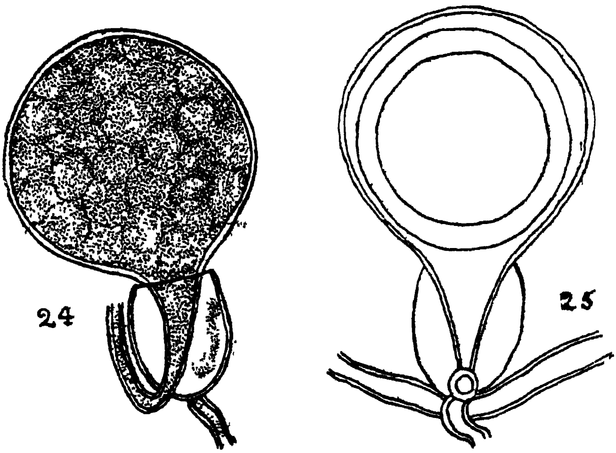
Germination of the chlamydospore takes place by means of a number of germ-tubes (Fig. 18); the abnormally thickened structures of bean and maize-meal cultures, however, have shown no power of further development.

Oogonia have not been observed in cultures on rich nutrient media, although carefully looked for; however, if these organs are only sparsely developed it is quite possible that they may have been overlooked. Oogonia are produced by this fungus, and were first seen in a plate culture prepared as follows:—A small portion of the mycelium was placed in prune juice for three days

at a temperature of 21°C. It was then washed in sterilized distilled water, and transferred to a plate of soil agar. When the plate was examined at the end of two weeks, the original inoculum showed a moderate number of oogonia with fully developed oospores. This method has been followed with success, but the sexual organs have always been restricted to the inoculum, and have never been observed on the scanty mycelial growth which spreads over the surface of the soil agar.

The oogonia are large, spherical bodies attached to the oogonial hypha by a well-defined, gradually-tapering stalk which, in most cases, lies within the basal antheridium. When young, the oogonium is thin-walled, colourless, and filled with numerous oil globules (Fig. 24; Plate I., Fig 3). Later, it becomes tinged with yellow, and as the oospore develops this coloration becomes intensified until a deep yellowish-brown colour results. The diameter of the oogonia varies considerably, and in 50 individuals ranged from 27 to 52·5μ with an average of 42·2μ.

The antheridium arises from a hypha which is distinct from that bearing the oogonium (Fig. 24), and usually entirely surrounds the basal region of the latter. At first the antheridium is thin-walled and hyaline, but later a slight thickening of the wall is accompanied by a coloration similar to that characteristic of the oogonium. The antheridium is very persistent, and varies in length from 18-25·5μ, and in breadth from 15-24μ.



FIGS 24, 25.—24. Antheridium and young oogonium. ×800. 25. Oogonium with mature oospore from the original inoculum of a 2 weeks' soil-agar culture. ×800.

The oospores are spherical, thick-walled, yellowish-brown bodies, which often do not quite fill the cavity of the oogonium (Fig. 25). The wall is 4·5μ in thickness, and the spore itself varies in diameter from 22·5 to 45·0μ with an average for 50 individuals of 35·3μ. The germination of the oospore has not been observed.

Culture Media.

The growth of the fungus isolated from diseased walnut roots, and above described, has been studied on several culture media.

Maize-meal Agar.—50 grs. of ground maize grains were steamed in 500 cc. of water for half hour, strained through wire gauze, 2% of agar added, and the whole made up to 500 cc. A thick white growth resulted on this medium, with aerial and submerged mycelia well developed. The aerial hyphae were even, sparingly branched, and at first non-septate. Many septa develop later, and the walls of the hyphae become very thick. No sporangia or oospores were produced. Chlamydospores were moderately developed on the aerial and very abundant on submerged mycelium, the wall of each becoming evenly and very considerably thickened over its whole surface.

Oatmeal Agar.—50 grams of crushed oats were steamed with 350 cc. water for half hour, strained through wire gauze, 2% agar added, with enough water to bring the quantity up to 500 cc., which material, after being brought to the boil, was tubed and autoclaved. In one week the culture had covered the surface of the plate, and the thick aerial growth reached a height of 1 cm. above the surface of the agar. The hyphae of the aerial mycelium were of constant diameter, sparingly branched, with numerous chlamydospores. The submerged and sub-aerial mycelia were also even with abundant chlamydospores arranged usually in clusters. The hyphae became septate, and some thick-walled; while many of the chlamydospores may become considerably thickened, the majority remain almost thin-walled even in old cultures. No sporangia or oospores were developed.

Bean-meal Agar.—50 grams of haricot beans were ground to a meal and added to 350 cc. water, steamed for half hour, strained through wire gauze, made up to 500 cc. with water and thickened with 2% agar. The aerial mycelium was thick and well-developed, reaching a height of 1·2 cm. above the surface of the agar. Its hyphae were regular, of even diameter, sparingly branched, thin-walled, continuous, at first quite sterile, but later developing a moderate number of chlamydospores. Submerged mycelium becomes irregularly swollen, and bears plentifully terminal chlamydospores, which may become very thick-walled by the deposition of rounded projections of cell wall substance. Oospores and conidia are not developed.

Potato Dextrose Agar.—Washed, but unpeeled, potatoes were cut into small cubes, 200 gms. were steamed in 1 litre of water for one hour, strained through cheese cloth, and made up to 1 litre with water to which 20 gms. of dextrose and 25 gms. agar were added. The aerial mycelium was well-developed, 1 cm. above surface of agar, though the growth was not as thick as that on maize, bean and oatmeal agars. The hyphae composing it were even and sparingly branched. The submerged mycelium was

irregularly swollen or gnarled. Chlamydospores were produced terminally or in little clusters or heads, and were thin or only slightly thick-walled, although the cells of the hyphae themselves frequently underwent considerable thickening. There were no conidia or sexual bodies.

Malt Agar.—3%. The surface growth attained a height of about 0·5 cm. above agar, but did not form a thick mat, the plate being transparent when held to the light. The surface hyphae were irregular in outline, and bore abundant chlamydospores in large groups. The submerged hyphae were very swollen and gnarled, with few perfect chlamydospores. The chlamydospores do not become very thick-walled, and oospores and conidia have not been observed.

Dilute Prune Juice.—Five prunes were cooked in 500 cc. water for half hour, strained through cotton wool, and filtrate made up to 500 cc. A quick and thick mycelial growth is obtained by planting in liquid prune juice. The submerged mycelium was thick, hyphae of which were very gnarled, with structures suggestive of imperfect chlamydospores, which, however, were probably merely swellings on the hyphae. A small amount of aerial mycelium was produced above the surface of the liquid, with even hyphae, and normal chlamydospores. Neither conidia nor oospores were developed.

Sterilized soil cultures have been considerably used, since on them conidia are always produced. Pieces of mycelium previously grown for at least three days in prune juice, and subsequently washed in sterilized water, were used as the inoculum. Growth was slow, and only a sparse mycelium produced. This, however, bore both conidia and chlamydospores, the latter being either intercalary or terminate on short lateral branches. No oogonia were noticed.

Soil Agar.—600 cc. water were added to 400 grams of Carrum sand and autoclaved at 125°C. for half hour. The extract was filtered through paper and the filtrate thickened with 1·5% agar. As in the case of soil cultures, here also the inoculum was previously grown for three or four days in dilute prune juice. The thin mycelium which gradually spread out to the edge of the plate was both submerged and closely applied to the surface of the agar, but no aerial growth was produced. Chlamydospores were only sparingly developed. The importance of this medium lies in the fact that oospores were developed in the original inoculum itself after growth of a week or more upon it. Conidia also were found in small numbers, but mainly on or near the inoculum.

Infection Experiments.

Only a few preliminary experiments have been made to test the capacity for growth of the fungus in living tissues.

1. The Castor Oil Plant (*Ricinus communis* L.).

Portion of the mycelium was placed on the upper surface of the lamina, near its junction with the petiole, of a young leaf of a seedling plant of the Castor Oil. Sterilized water was added in order to give sufficient moisture for the life and growth of the fungus, and the plant was covered with a bell jar; a non-treated plant being kept under identical conditions. After several weeks, one of the leaves of the infected plant turned brown, and assumed a water-soaked appearance, the apical region of the stem later exhibiting similar features, for a distance of about 5 cms. Portion of the stem was sterilized with 0·1% mercuric chloride solution, washed in sterilized distilled water, and sections made with a flamed razor were transferred to sterilized water and thence to oat agar plates. In a few days a non-septate mycelium had spread out from each of the sections, and the examination of the sub-cultures subsequently proved that a recovery of the original fungus had been made.

Sections of the stem were treated with lacto-phenol and cotton blue, when the presence of intercellular hyphae, particularly in the pith, was clearly distinguishable.

2. Fruits of the English Walnut.

Almost mature green walnuts were the only ones available. These were inoculated, under as sterile conditions as possible, with portions of the fungus, either by placing the mycelium directly upon the uninjured surface of the fruit, or by first cutting the surface with a sharp sterilized scalpel, and then placing the fungus over the point of injury. The infected fruits were placed in moist chambers, and kept at room temperature, controls being kept in every case.

In four days, a browning of the pericarp around the infection point was evident, in both types of inoculation, and this gradually extended until the whole of the mesocarp has assumed a dark-brown, water-soaked appearance. If the fruit was mature at the time of infection, splitting of the epicarp and mesocarp occurred, rotting of the tissues, however, continuing. If, as in several cases, the fruit was younger, the epicarp and mesocarp remained intact, turned dark brown, and a " dry rot " was established. The seed, also, became involved, the hyphae of the fungus which were seen on the surface of the endocarp being able to attack, penetrate and kill the young embryo. Hyphae also passed to the outer surface of the fruit, where they formed a white, fluffy, sterile growth.

Portions of the inner regions of the infected tissues were transferred to plates of 3% malt agar, and from these the fungus was readily recovered. An examination of sections of the brown, water-soaked tissues after treatment with lacto-phenol and cotton blue revealed the presence in them of numerous, branching, intercellular, non-septate hyphae.

3. Walnut Leaves.

Walnut leaves were placed in moist sterile petri dishes, and portions of the fungal mycelium were planted on the under surface, a drop of sterile water being added to each. Controls were similarly treated, but without the addition of the fungus. After four days, the leaf was blackened around the spot on which the fungus rested, the controls remaining unchanged.

4. Apple Fruits.

A number of ripe apples were used to test the pathogenicity of the fungus. The surface of the fruit was sterilized, and to this region the mycelium of the fungus was added, either with or without previous surface injury. The inoculated apples were kept in moist chambers at room temperature. Those fruits in which the surface layers were uninjured remained quite healthy until the end of the experiment, as did the controls. The injured apples, however, showed early evidence of fungal attack, since a brown rotting of the tissues soon appeared around the point of inoculation. This browning spread slowly around the circumference, the epidermal and deeper layers at the same time remaining intact. Finally, the entire apple became discoloured, and when cut open, showed that the whole flesh had been killed and browned. Examination of the tissues revealed the intercellular, non-septate hyphae of the fungus with a few small chlamydospores formed at intervals within them. The mycelium of the fungus was readily recovered from the dead tissues by ordinary methods of culture.

5. Walnut Seedlings.

Twelve to eighteen month old plants of the English Walnut were used for inoculation purposes, the fungus being planted either in the tissues of the stem near the ground level or on the surface of an exposed root.

The surface of the stem was treated with a 0·1% solution of mercuric chloride, washed with sterile water. A deep longitudinal incision was then made by means of a flamed scalpel, and into the pocket so formed, a three days old fungal colony, grown in prune juice, was carefully inserted. The wound was bound with moist, sterile cotton wool, and covered with oiled paper, the wrappings being kept moist for ten days with sterile water; after which time the coverings were removed. Controls were kept, and these remained healthy in every case.

In most instances infection became evident in ten days' time, and death followed within four weeks from the date of inoculation (Plate I., Fig. 1). In one case this was delayed for a period of three and a half months. The infected tissues assumed a brown coloration, and since the fungus travelled most rapidly in a vertical and only slowly in a tangential direction, this surface darkening appeared as a longitudinal strip of discoloured tissue

which extended from the wounded area. This longitudinal extension usually occurred both towards the stem apex and down through the hypocotyl to the root system. The fungus penetrated radially, and soon the tissue of the cortex, pith, phloem, and sometimes the wood were overrun by its intercellular hyphae. From such infected plants the fungus was reisolated without difficulty, and when examined showed all the cultural characters of the original inoculum.

Only a few preliminary experiments have been made, as yet, whereby infection has been established through root inoculation. In them, the terminal portion of the main root was exposed as carefully as possible, and wounded very slightly. The fungal culture was placed in position and bound to the root's surface with damp cotton wool. The wool was kept moist, and in three weeks' time the leaves wilted and the plant died. The tissues of the main, and secondary roots, hypocotyl, and stem to a distance of four inches from the point of inoculation were entirely browned, and showed in sections the presence of very numerous fungal hyphae.

The fungus appears to be far more widespread and luxuriant in its growth in infected seedlings than in the diseased tissues of adult trees. Rounded or oval swellings which cause considerable enlargement of the intercellular spaces are frequently present on the mycelium in the tissues of seedlings (Fig. 26). These closely resemble the chlamydospores produced by the fungus on nutrient media.

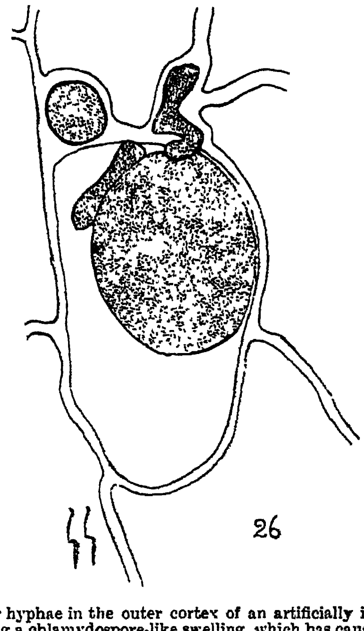


FIG. 26.—Intercellular hyphae in the outer cortex of an artificially infected Walnut seedling, showing a chlamydospore-like swelling, which has caused a considerable enlargement of the intercellular space. × 900.

Systematic Position of the Fungus.

From a study of the characters of the fungus isolated from the walnut roots, its affinity with members of the genus *Phytophthora* becomes clearly marked, and there seems no doubt that such is its generic position.

On account of the resemblances in the external symptoms of the disease with those characteristic of the "Gummosis" diseases of Citrus trees, a comparison with the organisms causing Brown Rot Gummosis, and Mal di Gomma Foot Rot (11) was naturally made.

Pythiacystis citrophthora Sm. & Sm. (20), the causal organism of Brown Rot Gummosis and Brown Rot of Lemon Fruits, has been recorded from Victoria by Brittlebank (2). In its typical form, the fungus only produces conidia, neither chlamydospores nor oogonia being developed. In this respect it differs markedly from the Walnut *Phytophthora* in which chlamydospores are a most characteristic cultural feature, and in which the production of oogonia can be definitely induced.

Pythiaceous forms have been isolated from several deciduous trees, including the Black Walnut by R. E. and E. H. Smith (21). Their strain "E" from the Walnut is of interest for comparison with the walnut *Phytophthora* under discussion. On fresh potato dextrose agar these authors report that the former yielded an abundance of oogonia and conidia, but no reference is made to the presence or absence of chlamydospores. The oospores average from 25-30μ in diameter, and the prominent antheridia are mostly paragynous, a position which has led to the suggested affinity with *Phytophthora cactorum* (Cohn and Lebert) Schroeter. Since oogonia and conidia are never produced on potato dextrose agar, while chlamydospores are abundant, and the oogonia are constantly amphigynous in the Victorian form, it would appear that the two organisms are distinct from one another. Several other strains which have been isolated from nursery trees of Almond, Pear, and Peach, have been described by these writers, but none of them agrees with the characters of the fungus under consideration.

The amphigynous nature of the oogonia suggests affinity with species of the Phaseoli group of *Phytophthora* as defined by Rosenbaum (18), which includes such forms as *P. parasitica* Dastur, *P. phaseoli* Thax., *P. infestans* (Mont.) de Bary, *P. erythroseptica* Peth., *P. arecae* Colem., *P. hibernalis* Carne, *P. Meadii* McRae, *P. colocasiae* Rac., *P. Faberi* Maulb., *P. cinnamomi* Rands., *P. cryptogea* Peth. and Laff., and *P. mexicana* Hot. and Hartge.

P. Faberi Maulb. (17) is distinguished from the Walnut *Phytophthora* in that it produces in cultures large numbers of more narrowly oval conidia which readily fall away from the coni-

diophore with a short refringent pedicel, and further sexual organs are only produced when it is grown in mixed cultures.

P. infestans (Mont.) de Bary need not be seriously considered since the conidiophores bear characteristic enlargements and smaller conidia, and the antheridia are often inconspicuous and not of constant occurrence.

In *P. phaseoli* Thaxt. (22) also the conidiophores undergo enlargement at the nodes, the sporangia are smaller, as also are the oospores than in the species under consideration, while the antheridia in the former are not persistent.

P. arecae Colem. (6), while showing some points of similarity to the Victorian form differs from it in the absence of chlamydospores. Similarly, *P. Meadii* (McRae, 14) only rarely develops chlamydospores in culture, and, as well, possesses more elongate conidia.

In *P. erythroseptica* Pethyb. (15) the most distinguishing feature is the inconspicuousness of the papilla of the conidium.

P. mexicana Hot. and Hartge (13) again has a more elongate conidium in which a very prominent papilla is evident, and chlamydospores are only sparingly produced.

P. hibernalis Carne (5) is distinct in that chlamydospores are never produced, while the conidia have a mean ratio of length to breadth of 2 or more, and fall from the conidiophore with a persistent pedicel.

One of the commonest forms of *Phytophthora* found in Victoria is *P. cryptogea* Pethyb. and Lafferty (16). This form has been studied by Brittlebank and Fish (3) who find that after the production of the sporangium the growth of the fungus is continued, a new sporangium being produced either in the old sporangium or a short distance from it. This feature has only once been seen in the Walnut species, while the oospores of the latter have a much higher average diameter.

P. colocasiae Rac. as described by Butler and Kulkarni (4) has elongated sporangia which are readily detached from the conidiophore with persistent pedicils. The oospores average 23μ in diameter, showing a difference of over 10μ from that of the walnut fungus.

P. cinnamomi Rands. (1) has oospores and oogonia which approximate closely to those described above for the walnut species, but the development of obpyriform sporangia without papillae clearly distinguishes the two forms.

The walnut fungus, on the whole, shows closest affinity with *P. parasitica* Dastur (8) although it differs very considerably from the size of the various spore types given in the original description of this species. Fawcett (10) has isolated from citrus trees suffering from Mal di Gomma foot rot a strain of *P. parasitica* which is identical with a fungus attacking the tomato and described as *P. terrestris* Sherbakoff (19). Godfrey (12)

has described a new variety of *P. parasitica* as the cause of foot rot of Rhubarb, while many other strains have been isolated from a variety of hosts.

Ashby (1), from a recent study of many of these strains, has given an emended and broader description of *P. parasitica,* and it is with this description that the characters of the fungus now being considered will be compared.

The conidia of the walnut *Phytophthora* agree in size and shape with those of *P. parasitica*, having a mean ratio of length to breadth of 1·5, and an average length of 55·9μ and breadth of 36·6μ. These bodies are not, however, produced in cultures on standard media, as is generally the case with the majority of the other strains. However, as in some of the latter their production is very scanty, it is thought that this cultural feature should not present a serious distinction.

Chlamydospores are formed in abundance by most *P. parasitica* strains, as they are in that from the walnut. In the latter, however, they remain hyaline throughout their life, never becoming coloured as has been described for other types.

The sexual organs are identical with those of the species considered, but they have not so far been found in ordinary cultures on such media as bean and oatmeal agars, as in other strains. The oogonia and oospores obtained by the method above described are large, and the average diameter higher than in the known strains, since the average diameter of the oospore is 35·3μ with a range from 22·5-45·0μ.

Ashby has now divided *P. parasitica* into two groups—

1. Microspora, in which the oospores have a mean diameter under 20μ with a range of 12-24μ.
2. Macrospora, with oospores of a mean diameter of over 20μ and a range of from 20 - $\pm$35μ.

It will be seen, therefore, that the walnut strain must fall into the second sub-group of large-spored forms, and in doing so becomes separated from the organism causing Mal di Gomma foot rot of Citrus, i.e., *P. terrestris* Sherbakoff, which falls into the small-spored division.

P. parasitica has not been recorded as occurring in the State of Victoria, and it appears doubtful as to whether its presence in Australia has previously been noted. Mr. C. C. Brittlebank has very kindly shown me some unrecorded observations that he has made on an organism isolated by him on 25th February, 1925, from diseased Pine seedlings grown at the Forest Plantation, Creswick, Victoria, and assigned by him at that time to Dastur's species. It would seem then that his isolation marks the first discovery of this form in this State.

This work has been carried out in the Agricultural School of the University of Melbourne, and I wish to thank Professor Wadham both for his kindness in placing the facilities of his department at my disposal, and for his interest in and help during

the progress of the investigation. I am grateful to Mr. E. C. Dyason for arranging for the regular supply of diseased material from the groves at Wandiligong, and to Mr. A. O'Brien I am indebted for the photographic illustrations.

Summary.

1. The hyphae of a phycomycetous fungus have been demonstrated and traced in the inner region of the bark of diseased roots of the English Walnut (*Juglans regia*).

2. These hyphae are intercellular in secondary phloem and cambium; intracellular in the youngest layers of the wood.

3. A fungus showing characters typical of the genus *Phytophthora* has been isolated.

4. Conidia germinating either by means of zoospores, or more rarely directly by one or more germ tubes, are produced when active cultures are transferred to and grown on sterilized soil.

5. Conidia have an average length of 55·9μ, a breadth of 36 6μ, and an average ratio of length to breadth of 1·50.

6. Chlamydospores are very abundantly produced by the fungus when grown on maize-meal, bean-meal, oat-meal, agars, etc. They are hyaline, spherical bodies with a diameter ranging from 13·5 to 64 5μ, and showing a mean of 35 96μ.

7. Oogonia are produced when an active culture of the fungus is transferred to soil agar. They only occur among the hyphae of the original inoculum. They are yellowish-brown bodies with a diameter ranging from 27 to 52·5μ, the average being 42·2μ.

8. The antheridium completely surrounds the base of the oogonium. It is at first hyaline, later becoming brownish, and is persistent. The oospores are thick-walled, yellowish-brown, and vary in diameter from 22·5 to 45·0μ, an average of 50 individuals being 35·3μ.

9. The taxonomy of the fungus is discussed, and its affinity with *P. parasitica* Dastur, in the wide sense suggested by Ashby, is supported.

10. The fungus isolated and described has proved pathogenic to seedlings of *Juglans regia*, and from them has been reisolated in pure culture.

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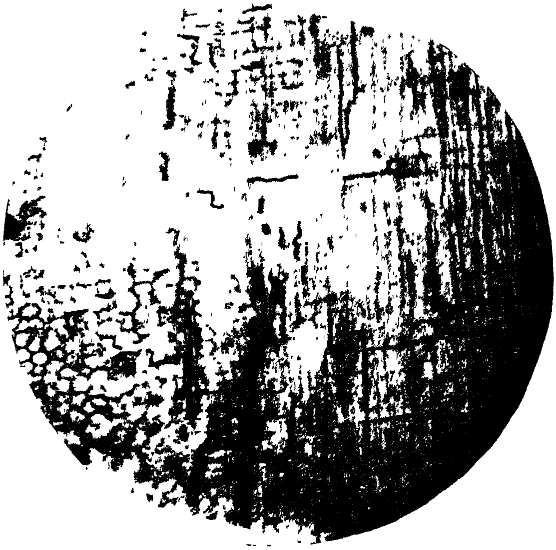

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EXPLANATION OF PLATE I.

FIG. 1.—18 months old Walnut seedling, 9 weeks after inoculation with *Phytophthora parasitica,* showing wilted condition of leaves.

FIG. 2.—Radial longitudinal section of hypocotyl of infected seedling, showing intercellular hyphae in cortex and secondary phloem. ×100.

FIG. 3.—Amphigynous oogonia from a culture. ×375.

Appendix.

The relation of the Fungus to trees in Victoria.

By Professor S. M. WADHAM.

The preceding description of the fungus, and its occurrence and its life history, reveal certain facts of particular significance to the cultivation of walnuts.

Mr. Fontradona was of the opinion that the majority of walnut trees which had died in the district were killed by this fungus, although *Armillaria mellea* had certainly claimed a number of victims in the groves which have been the particular study in this present investigation.

The occasional appearance of the crown rot in trees which are widely scattered over the country side, seems significant in the case of a fungus with no wind-borne spores. This is of particular interest in view of the fact that many of these individuals were raised from nuts, and not imported from nurseries. Some of the trees have been attacked after they have been growing successfully for many years. The Buckland Valley affords several examples. It seems reasonable to suppose that the fungus has come to these trees from the luxuriant wild tree growth which is characteristic of the bush of the district. In some cases, infected individual trees have been on the banks of creeks, and it is possible that the infection has taken place by spores carried on to the roots by water. In other cases, the mycelium may have spread through the soil in a vegetative manner on humus or dead roots. The ease with which it continues a saprophytic existence, suggests that this is quite feasible, provided that the humus is available in sufficient quantity.

As a general rule, the ground round most walnut trees in the district is uncultivated, and the plants themselves do not thrive after the first few years unless the soil is a very deep one. On the Wandiligong groves, cultivation is practised at present, but in view of the danger of conveying phytophthora-infected humus from tree to tree and also of the damage to roots, the depth to which this cultivation is carried on may have to be reduced. Further, intercropping and greensoiling with peas, which seem desirable practices from the point of view of increasing the humus content of the soil, and consequently its power of retaining water, require further consideration. For the investigation has shown that leguminous materials are a good material for the culture of the fungus.

In California walnuts are usually irrigated, and in the Ovens Valley, those which are near creeks frequently make the best trees from a vegetative point of view. It may be that in the future irrigation will be applied to walnut production. If creeks which run through the " bush " are used for this purpose care will have to be taken in order that the motile spores are not introduced into the groves. It is hoped that further work on the viability of the spores under aquatic conditions may be carried out in the near future.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. I., 1929.]

ART. III.—*A Collection of Graptolites from the Federal Territory.*

By WM. J. HARRIS, M.A., and R. A. KEBLE, F.G.S.

(Palaeontologist to the National Museum, Melbourne, and Geological Survey of Victoria.)

[Read 9th May, 1929; issued separately 9th October, 1929]

The present collection of graptolites from four miles south of Queanbeyan—the first collection to be described from the Federal Territory as far as we are aware—was made by Mr. G. Milliard, of Federal Parliament House, Canberra. It consists of about 30 slabs of bluish-grey very fissile slate, or, more correctly, shale showing considerable iron-staining, the details of the graptolites being in nearly all cases indistinct. If it is possible to obtain specimens from less weathered portions of the fossiliferous band, some fine examples may be found. The fossils in the present collection are in most cases preserved as white films on the shale, and only four genera seem to be represented, viz., *Dicellograptus* (very common), *Dicranograptus*, *Diplograptus*, and *Climacograptus*.

Two species of *Dicellograptus* occur, but the thecal characters on which accurate determination depends are not well shown. The larger species is a heavy form which may be compared with *Dicellograptus gravis* K. and H. (1) from Mt. Easton, and the Yarra Track near Matlock, Victoria. It resembles *D. morrisi*

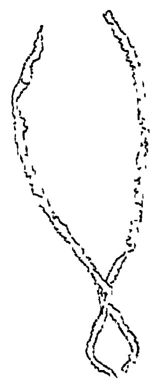

FIG. 1.—*Dicellograptus* cf. *gurleyi*. Natural size figure, showing re-crossing stipes.

Hopk., but has a squarer axil. A form which may be identical with it, but which seems to be poorly preserved, is figured by T. S. Hall (2) as *D. divaricatus.* Hall's figure, however, shows a rapid divergence from the sicula. The second *Dicellograptus,* in its proximal portion, resembles *D. elegans* Carr. The stipes diverge in the typical caliper fashion, but then approach each other and cross, again diverging and approaching, so that they form an incomplete figure **8.**

Occasional specimens show the stipes re-crossing. A similar crossing of the stipes is described by Elles and Wood as characteristic of *Dicellograptus caduceus* Lapw., but in that form the crossing takes place comparatively near the sicula, in our form usually more than 20 mm. distant. The Canberra form may be better compared with *D. gurleyi* Lapw. (4). Where the first crossing is not shown, the specimens are indistinguishable in external appearance from *Dicellograptus elegans.*

Of the Diplograptidae, *Diplograptus calcaratus* var. *vulgata, D. ingens,* and *Climacograptus tubuliferus* are specifically determinable, but better material would enable other species to be made out.

The list is therefore—

Dicellograptus cf. *gravis* K. and H. (very common).
D. cf. *gurleyi* Lapw. (very common).
Dicranograptus furcatus cf. var. *minima,* Lapw.
Diplograptus calcaratus var. *vulgata* Lapw. (fairly common).
D. ingens T. S. Hall.
Climacograptus tubuliferus Lapw.

Although the species represented are so limited in number they provide some evidence of the horizon of the beds. The presence of species of *Dicellograptus* of the type shown indicates an Upper Ordovician horizon, but not the lowest zones of the Upper Ordovician. Similarly the absence or comparative rarity of *Dicranograptus* may be regarded, in the present state of our knowledge, as showing that these beds are not near the summit of the Upper Ordovician. At present we know of no Victorian locality with the same association, but it is very probable that some of the Mount Easton beds are on about the same horizon. Several New South Wales graptolite localities—all Upper Ordovician—are mentioned by Hall (5), but the species recorded from most of these are so few that comparison is difficult. The associations at Tallong and Stockyard Creek seem to be different, but more complete collections will be necessary before exact comparisons can be made, especially with the forms occurring at Currowang and Lawson.

The Federal Territory association has its equivalent in Britain with the *Dicranograptus clingani* or Zone 12 of Elles and Wood's (6) tabulation of the British forms.

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ART. IV.—*A Note on some Experiments dealing with Sulphur Treatment of a Soil and its effect on Wheat Yield.*

By MARY D. GLYNNE, M.Sc.

(Rothamsted Experimental Station, Harpenden, Herts.)

(Communicated by Professor S. M. Wadham.)

[Read 13th June, 1929; issued separately 16th October, 1929].

Contents.

Introduction.

A plot of land in the grounds of the Agricultural Department of Melbourne University has had wheat grown on it continuously for fourteen years. Latterly the yield has been poor, and the plants have produced a large proportion of sterile heads. It was thought that this might be due to the presence in the soil of fungi, causing foot and root rot diseases. The present investigation was undertaken to test the effect of certain soil treatments with the possibility in view of finding a method which would reduce the disease without adversely affecting the crop. In certain English soils treatment with sulphur (1) and sulphuric acid (2) has reduced Wart Disease of potatoes caused by *Synchytrium endobioticum*, an organism which infects from the soil. There was, however, a general tendency for the heavier treatments to depress the yield. Treatments which had given promising results with Wart Disease were tried in the present experiment, which was carried out at the School of Agriculture, University of Melbourne, during the tenure of the Australian Fellowship of the International Federation of University Women.

Present Investigation.

Sulphur was applied to certain plots as flowers of sulphur and sulphuric acid containing equal quantities of the element sulphur

was applied to others. Lest the acid should affect the disease but at the same time make the soil too acid for fertility, some plots after treatment with acid were left for a few days in which it might act on the organisms, and then equivalent amounts of calcium carbonate were applied to counteract the acidity. Controls with calcium carbonate alone were laid down. The effect of the fertiliser ammonium sulphate was also tested for comparative purposes.

Soil.

The land used in the present investigation is enclosed in wire netting to protect the crop from birds. It carried manurial tests about 1912. After this the soil was very thoroughly mixed and cultivated to obtain uniformity. It has borne an annual crop of wheat since 1914, with an application of 1-2 cwts. per acre superphosphate about every second year, and of 1-2 tons per acre of lime about 1923, and an application of road scrapings about the same time. The soil consists of a light loam, dark grey in colour, and of very even texture, which is not typical of the district. The crops appear to have deteriorated within recent years, and are recorded as poor in 1926 and 1927.

Treatment.

The quantities of each chemical applied were calculated so as to supply the element sulphur to the soil in the proportion of 0·05, 0·10, and 0·15%. Treatment of the soil was effected between June 23rd and 26th, 1928. Plots one yard square were marked off by means of two galvanised iron strips 9 inches wide and two yards long, bent in the middle at right angles, so that when fitted together they made a square. These were pushed into the ground, and 300 lbs. of soil were removed from the plot, weighed, spread out on a galvanised iron tray 48 in. x 48 in. and 6 in. deep, and well mixed with the various chemicals. The soil was then replaced in the plots, and the surrounding strips removed. The control plots were treated in the same way, omitting the chemical treatment. Sulphur, calcium carbonate and ammonium sulphate were applied in the solid state. Sulphuric acid was first made up to 2½ litres in water.

Federation wheat was sown on June 30th. In each plot there were four rows eight inches apart, with sixteen grains in a row. Observations were made at least fortnightly throughout the season, and the crops harvested on 11th December, when pH determinations of the plots were made. Sulphate estimations were made on certain plots before sowing and after harvest.

A general survey of the disease present was made by a superficial examination of the plants before harvest. After harvest the bases of all the wheat plants were cut off about an inch above the crown, and those obtained from each row were put in separate damp chambers. After a period for incubation these were examined for parasitic fungi.

Observations.

Germination was observed to have taken place very evenly in about eighteen days, and during the first six weeks no differences could be detected between the controls and the treated plots. After eight weeks differences began to show, and the plants on plots treated with sulphur, sulphuric acid both alone and with lime, and with ammonium sulphate developed a deeper green, and became taller and more robust than the controls or those which had received lime alone. These differences increased as the season advanced, so that the general appearance of the plots was not unlike that of plots at Rothamsted to which a nitrogenous manure had been applied, causing the production of a dark green robust growth.

Crops.

The crops obtained from the different plots are shown in the table. The five controls gave a consistently low yield, varying from 29·2 to 61·3, with an average of 47·0 gms. per square yard of total straw and grain. The grain alone averaged only 1 gm. per square yard, or approximately 0·18 bushels, or 10 lbs., per acre. The pH did not vary much round an average of 7·57.

Sulphur treatment gave a remarkable increase in both straw and grain, each of which increased with the amount of sulphur applied. The largest total increase amounted to over 800%, while the grain in the most heavily treated plot amounted to 162·6 gms. per square yard, or 28·9 bushels per acre. The acidity of the soil increased with the amount of sulphur added, as did the sulphate content of the soil.

Sulphuric acid supplying 0·15 and 0·10% sulphur gave a large increase in crop. Duplicate plots giving 0·1% sulphur showed rather large differences in final yield, though up to the last month they looked very similar. This may have been partly due to the fact that the one producing the larger crop was next to a path and the other was situated between two plots bearing heavy crops so that lack of moisture may have been a limiting factor. No explanation can be offered for the difference in pH or the fact that the acidity of a plot receiving 0·1% S as sulphuric acid is greater than that in the plot receiving 0·15% S. The sulphate content of the latter was higher than the former, and corresponded roughly with the amount of acid added. A larger number of duplicate plots are needed to give quantitative results. The main result of the treatment with sulphuric acid is a large increase of crop corresponding with increased soil acidity.

The addition of lime after treatment with sulphuric acid did not reduce the crop, as compared with that produced when sulphuric acid was applied alone, but in general gave a slight and possibly insignificant increase. The addition of calcium carbonate equivalent to the acid applied did not restore the soil to its

YIELD AND pH OF PLOTS TREATED WITH SULPHUR, SULPHURIC ACID ALONE AND WITH LIME, LIME ALONE AND AMMONIUM SULPHATE.

TABLE I.

TREATMENT	Sulphur applied as % of soil	pH	YIELD in grams Straw	Grain	Total	Bushels grain per acre
Control	—	7·66	55·0	0	55·0	
	—	7·77	46·5	0·1	46·6	
	—	7·42	58 3	3·0	61·3	
	—	7·57	41·1	1·9	43·0	
	—	7 47	29·1	0·1	29·2	
Average	—	7·57	46·0	1·0	47·0	0·18
Sulphur	0·15	5·69	271·4	162·6	434·0	28·9
	0·1	5·98	169·5	76·3	245·8	13·5
	0·1	6 43	111·2	33·2	144·4	5·7
	0·05	6·77	64·5	5 9	70·4	1·0
H_2SO_4	0·15	6 60	240·1	71 9	312·0	12 8
	0·1	5.52	237·9	140·1	378·0	24·9
	0·1	6 65	217·0	66·5	283.5	11·8
	0·05	7·17	80·5	4·2	84·7	0·7
$H_2SO_4+CaCO_3$	0 15	6·61	226·7	148·7	375 4	26·4
	0·1	6·59	175 5	115·2	290 7	20·4
	0·05	6·98	72 8	1·1	73·9	0·19
$CaCO_3$	0·15	—	69·8	1·5	71·3	0·19
	0·1	7·62	54·6	9·8	64.4	1·7
	0·05	7·56	48·0	0·3	48·3	0 05
Ammonium sulphate	0·05	6·49	176·1	46·3	222·4	8·2

original pH, but left it slightly acid. Part of the carbonate could be seen as a fine white powder in the soil at the end of the experiment, showing that it had failed to react with the acid.

Lime alone gave small, but not very significant increases in crop, and increased the pH slightly.

Ammonium sulphate applied in a quantity sufficient to supply 0·05% sulphur, i.e., 26·7 cwts. per acre of the fertiliser, gave a greater increase in crop than the same quantity of sulphur applied as the element or as sulphuric acid either alone or with lime. It also increased the acidity to about the same amount as 0·1% sulphur applied in these other forms.

Disease.

The amount of soil-borne disease apparent in the crop was very small. A few plants were found affected with *Ophiobolus graminis* before harvest. Few disease organisms were observed developing on the bases of plants kept in damp chambers, but *Helminthosporium* sp. was found from four plots (control, calcium carbonate and two sulphur treated plots).

Discussion.

While the experimental evidence is insufficient to lead to definite conclusions, a consideration of possible factors leading to these remarkable increases in crop may be of value.

The apparent scarcity of soil-borne disease suggests that, contrary to the original supposition, factors other than disease were responsible for the poor crops obtained in recent years. And the fact that the diseases found were not more plentiful on the control than on the treated plots would seem to indicate that some factor other than the suppression of disease resulted in the large increases in crop obtained.

A general tendency is seen for increase in crops to accompany increase in soil acidity, but the fact that as good a crop is obtained with sulphuric acid followed by equivalent lime as with sulphuric acid alone indicates that yield does not depend directly on soil acidity. The acid, however, might dissolve compounds such as those of phosphorus, potassium, calcium and magnesium, making them more readily available to the plant, and if the soil were deficient in these compounds, increases in crop should result. The addition of lime might throw these compounds out of solution, but they would probably be left in a state more readily available to the plant than in the original soil.

Another possibility is that the original soil suffered from a sulphur deficiency, in which case similar increases in crop might result from sulphuric acid treatment applied alone or followed by lime, and from treatment with sulphur. Striking increases in crop, notably of alfalfa, have been obtained in Oregon (3), where large areas of soil appear to be deficient in sulphur.

The fact that ammonium sulphate gives a greater increase in crop than the same quantity of sulphur applied either as the element or as sulphuric acid suggests a deficiency of nitrogen. Some of the American work indicates a close relation between sulphur and nitrogen supply, suggesting that the former has a stimulating influence on the nitrogen-fixing bacteria. There may be a connection between this and the greater depth of green colour seen in the treated plots, which suggested the appearance of crops to which nitrogenous fertilisers had been applied.

Further investigation is desirable to discover the causes underlying the large increases in crop obtained.

From a practical point of view it seems very desirable that other soils should be examined to see whether they respond in a similar way.

Summary.

A plot of land on which wheat has been grown continuously for fourteen years has recently yielded poor crops.

Large increases in crop were obtained by soil treatment with equal quantities of sulphur applied as sulphur and as sulphuric acid.

Similar increases were obtained when calcium carbonate was applied after sulphuric acid, as when the acid was used alone.

Calcium carbonate alone gave a slight and relatively insignificant increase in crop.

Ammonium sulphate gave a larger crop than the same quantity of sulphur applied as the element or as sulphuric acid.

Only a small amount of disease was found, and this was no more common in the controls than in the untreated plots, so that the results appear to depend on non-pathological factors.

Although increase in crop is in general accompanied by increase in soil acidity the fact that the addition of lime did not depress the yield obtained with sulphuric acid suggests that soil acidity is not the chief factor. Acidity would, however, tend to bring other elements such as phosphorus, potassium, calcium and magnesium into solution, and though lime might throw these out of solution; they would probably be left in a state more readily available to the plant than in untreated soil.

A sulphur deficiency of the soil would explain the results obtained. Such a deficiency has been found in large areas in Oregon.

The larger increase in crop obtained with ammonium sulphate than with an equal quantity of sulphur as the element or the acid suggests a nitrogen deficiency.

The possibility is indicated that sulphur may have an effect on the nitrogen-fixing bacteria, which may be related to the dark green appearance of the treated plots.

Further investigations into the cause of the results obtained are desirable, and further investigations into other soils to see if they respond in the same way.

In conclusion, I would like to express my thanks to the many Australian friends who have done so much to facilitate my work while I have been in this country, and particularly to Professor Wadham, who has also extended to me the hospitality of his department.

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ART. V.—*Note on the Evidence of Age of the Dacites and Associated Igneous Rocks in the Marysville-Taggerty District, Victoria.*

By EDWIN S. HILLS, M.Sc.

(Demonstrator and Kernot Research Scholar in Geology in the University of Melbourne.)

[Read 11th July, 1929; issued separately 31st October, 1929.]

Introduction.

The purpose of this note is to record the observation of some significant facts bearing on the question of the age of the dacites and associated igneous rocks in the Taggerty and Marysville districts in north-western Gippsland, and hence on the age of similar rocks in other parts of Victoria. The conclusions reached are as yet tentative, and finality will not be approached until after the completion of further palaeontological and petrological research. It was thought, however, that some indication of a probable future change of ideas ought to be presented, in view of possible effects on the work of other geologists.

Summary of Results.

(a) TAGGERTY.

While investigating the igneous rocks of the Blue Hills, Taggerty, last year, I was lucky enough to find a fossiliferous bed in sediments underlying a thick rhyolite sheet forming the summit of that range. The following forms were subsequently described (1):—

Ostracodermi. *Bothriolepis gippslandiensis* Hills, 1929.
Dipnoi. *Eoctenodus microsoma* Hills, 1929.
Holonema cf. *rugosum* (Claypole, 1883).

It was shown that this assemblage is a typically Upper Devonian one, the genera *Bothriolepis* and *Holonema* never occurring outside that series in any other part of the world, and the characters of the new genus *Eoctenodus* being such as to be in accord with a determination of its age as older than any known *Ctenodus*, which genus first occurs in the Lower Carboniferous (*C. interruptus*, Carboniferous Limestone and Calciferous Sandstone of Fifeshire and Midlothian).

The presence of beds of Upper Devonian age in this locality had not been previously suspected, and since it was known that normal Palaeozoic dacites occurred to the east of the rhyolites as well at Marysville and Narbethong to the south, the very interesting question of the relation of the rhyolites and sediments to those dacites was opened up.

It was noted that at Narbethong very similar rhyolites, outcropping in an analogous way, had been described by Junner (2) as underlying and congenetic with the dacites, and further that Junner had compared the rhyolites with those at Mt. Wellington described by Teale (3) as underlying conformably Lower Carboniferous or Upper Devonian sandstones. Thus the implication was that the dacites are of Lower Carboniferous or Upper Devonian age.

Further collecting in the Taggerty district has resulted in the discovery of many well preserved though isolated placodermatous plates, the greater proportion of which are referable to *Bothriolepis.* The species *B. gippslandiensis* was founded on a detached median occipital plate and portion of a pectoral appendage. the first showing the V-shaped course of the sensory groove, and the latter the strong denticulations characteristic of *Bothriolepis.* The newly obtained material includes a pre-median plate, pectoral appendages and body plates, as well as another median occipital. Where these plates have any distinguishing characters of generic importance they are referable to *Bothriolepis,* and the presence of a remarkable median dorsal crest links them closely with *B. cristata* of the Upper Old Red Sandstone of Scotland, for which neither the median occipital nor the pectoral appendages have yet been described in detail.

Some fragments of a smaller placoderm with an ornament of fine concentric rugae were also obtained, as well as small pieces of plates or scales with an ornament similar to that of the large plate previously (1) referred to *Holonema.*

(*b*) Marysville.

The southerly extension of the Upper Devonian rocks of Taggerty has been recognized at Marysville, where the formations preserve their distinctive characters practically unchanged. The sequences in the two localities are as follows:—

Taggerty.	Marysville.
5. Rhyolite α.	5. Rhyolite α.
4. Rhyolite β.	4. Rhyolite β.
	Andesite, ? position.
3. Melaphyre.	3. Melaphyre.
2. Tuffs and fossiliferous sediments.	2. Tuffs, as yet barren.
1. Basal conglomerate.	1. Basal conglomerate.
Unconformity.	
Silurian, Cathedral Beds in part.	Silurian.

The outcrop of the rhyolite α at least is continuous between the two areas, but the intervening part was not studied in sufficient detail to permit of the recognition of the other formations, although east of Buxton the rhyolites α and β, the melaphyre, and the basal tuffs were seen (1).

The rhyolite α, which is very thick, and which forms the top of the steep escarpment marking the edge of the igneous rocks wherever they outcrop, has been traced south-west from Marysville to link up with the eastern edge of the area mapped by Junner, and there is thus no doubt that the correlation previously made between the Taggerty and Narbethong rhyolites from their descriptions and analyses is correct.

Junner's conclusion that the dacites overlie the rhyolites was confirmed. The latter outcrop everywhere marginally to the dacites, and may be seen to pass under them on the Wood's Point road and at Wilk's Creek. A few hours spent on the eastern side of the outcrop some thirteen miles from Marysville at Cumberland enabled me to recognize the rhyolites α and β as well as an andesite, overlying tuffs which rest on the Silurian, and again forming a border to the dacites. The rhyolite is known to occur at the edge of the dacites east of Mt. Torbreck. These facts, together with the pronounced V'ing in the streams, show that we are dealing with a series of lava flows, of which the order of extrusion is melaphyre, (andesite), rhyolite β, rhyolite α, dacite. The dacites and rhyolites at Narbethong have been shown to be congenetic, and this is borne out by the field and microscopic relations of the Marysville rocks, so that we may group them together as an Upper Devonian series. Some evidence was also found of the intrusion of the granodiorites into the rhyolite α.

Discussion.

On petrologic grounds, the Marysville dacites have been linked with practical certainty with the Mt. Dandenong, Mt. Macedon, and Strathbogies dacites (4). The latter underlie sandstones supposed to be Lower Carboniferous (5), and overlie the Silurian, so that a Devonian age is indicated. They were placed in the Lower Devonian, it being believed that the igneous activity was associated with strong epi-Silurian fold movements in Victoria. The field relations at Tolmie, however, do not suggest the existence of an unconformity between the dacites and the sandstones as great as from the Lower Devonian to the Lower Carboniferous. Indeed, the relations seem very similar to those described by Teale (3) between the rhyolites and sandstones at Mt. Wellington. The many points of similarity between the Taggerty rhyolites and sediments and the rhyolites and "basal beds" of Mt. Wellington suggest their correlation, and thus we may link the normal dacites and rhyolites (Marysville, etc.), the Strathbogies-Whitfield dacites, and the Wellington rhyolites as Upper Devonian, leaving open the question of the age of the overlying sandstones and conglomerates.

With regard to the granodiorites which are often associated with the lavas, it has been shown that they intrude the latter at Belgrave (6), Narbethong (2), Marysville and Warburton (7),

but they have generally been placed very close to them in age, being merely the intrusive phase of the igneous paroxysm which gave rise to the acid lavas. However, evidence has been forthcoming that granodiorites in the Grampians are post-Lower Carboniferous (8), and in the Tabberabbera district "A big hypabyssal or small plutonic intrusion of diorite porphyrite occurs in the Middle Devonian rocks. . . ." Thus the ". . . long maintained view that notable compressive earth movements with accompanying plutonic intrusions ceased in the Lower Devonian period cannot now be entirely accepted." (9).

Conclusions.

Evidence has been adduced to show that the dacites and associated lavas of the Marysville-Taggerty district are of Upper Devonian and not Lower Devonian age, as was previously believed. This necessitates a revision of our conception of the age of the other Victorian dacites, and those that can be linked petrologically with the Marysville rocks must also be placed in the Upper Devonian, the associated granodiorites being correspondingly affected.

The foregoing statements have been made in a positive manner for the sake of clarity, although complete investigation of the evidence has not yet been made. I have to thank Dr. H. S. Summers for advice on various matters connected with this paper.

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[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. I., 1929.]

ART. VI.—*Studies in Victorian Spiders, No. 1.*

By L. S. G. BUTLER.

[Read 11th July, 1929; issued separately 31st October, 1929.]

Introduction.

This paper deals with five spiders, the introduced *Oecobius navus* Blackwall, and four others which are new. Three new genera have been erected, *O. navus* has been redescribed, and the families Archæidæ and Palpimanidæ are now recorded from Australia.

The species referred to as *Corasoides australis*, gen. et sp. nov., superficially resembles the European spider *Agelena labyrinthica* Walck. (1), in its habits and the structure of its web. Investigation proves that there is a definite variation. The late Mr. Rainbow (2) recorded *A. labyrinthica* from New South Wales, but its presence in Australia must be doubted until further proof is forthcoming, as the writer is of the opinion that the spider recorded is *C. australis*, sp. nov., or a kindred species.

A new genus near *Aviola* is required to contain *Neoaviola insolens*, gen. et sp. nov. An interesting feature of this minute spider is the position of the spinnerets, which are placed in a transverse row across the posterior end of the abdomen. Two other spiders with this feature have been recorded from Australia, but they belong to the genus *Scotopsilus*.

The most interesting of the series is *Archaea hickmani*, sp. nov., of the family Archæidæ. This unique family was created by C. Koch (3) to contain a few species found in the Baltic amber. For many years it was considered to contain only fossil forms, until Cambridge (4) described a living form from Madagascar. Recently Hewitt (5) recorded a second living form from South Africa, and the present species from Victoria is the third recent spider of this rare family. By its presence in the Baltic amber it will be seen that the family is an ancient one; being of the Oligocene period, the age of these fossils can be counted in millions of years.

The species *Sternodes foraminatus*, gen. et sp. nov., is placed in the family Palpimanidæ as Petrunkevitch (6) has moved the Hermippeæ group, which contains this new genus, into this family. None of this group has been previously recorded from this continent, with the result that *S. foraminatus* is the first record of the family Palpimanidæ in Australia. It has an uncommon shaped sternum, also found in an American spider, *Dysdera interrita*, as figured by Comstock (7, p. 298). Other Victorian spiders with this feature in the writer's collection will be described later.

The introduced and almost cosmopolitan species *Oecobius navus* Blackwall, was originally described from specimens found on the Island of Madeira. Blackwall gives a very detailed description of the colour pattern, but includes very little else. In view of the absence in the paper of any figures, the incomplete description, and the fact that it was described from an immature form, it has been considered necessary to redescribe this small species.

Comstock's (7) terminology has been mainly used, and the classification of Petrunkevitch (6) has been followed. All measurements are in millimetres. The total length does not include the chelicerae.

The types, which are in the author's collection, stored in glass tubes that have been sealed by fusing with heat (8), will shortly be presented to the National Museum, Melbourne.

The author acknowledges the help given in translating keys and other detail by the Rev. E. Nye, of Wesley College, and Mr. C. Oke.

Family AGELENIDAE.

Sub-family AGELENINAE.

Genus **Corasoides**, nov.

Spinnerets normal. Eyes eight, in two rows of four, A.M.E. largest. Anterior row slightly procurved, posterior row more strongly procurved. Clypeus broad. Inferior margin of the chelicera has six teeth. Legs strong and robust.

CORASOIDES AUSTRALIS, gen. et sp. nov.

(Text-Fig. 1, Nos. 1-5.)

Female.

Total length 12·8 mm. Length of cephalothorax 6·0 mm. Breadth of cephalothorax 4·5 mm. Length of abdomen 6·8 mm. Breadth of abdomen 5·0 mm. Length of chelicera 3·6 mm. Breadth of chelicera 2·1 mm.

Cephalothorax.—Longer than broad, front square, sides constricted near the coxae of the first pair of legs, posterior edge hollowed at the pedicel. Head elevated, sloping down to a well-marked cervical groove. Ocular area evenly spread. Hairs on the top and front of the head. Thorax convex.

Eyes.—Eight, evenly spaced in two rows of four, both lines are procurved, posterior line more strongly so. A.M.E. largest, circular, others elliptical. All hyaline, and of a pale amber colour, A.M.E. 0·24 mm., P.M.E. 0·18×0·14 mm., A.L.E. 0·24×0·16 mm., P.L.E. 0·2×0·08 mm.

Chelicera.—Formidable, robust, a distinct boss is present.

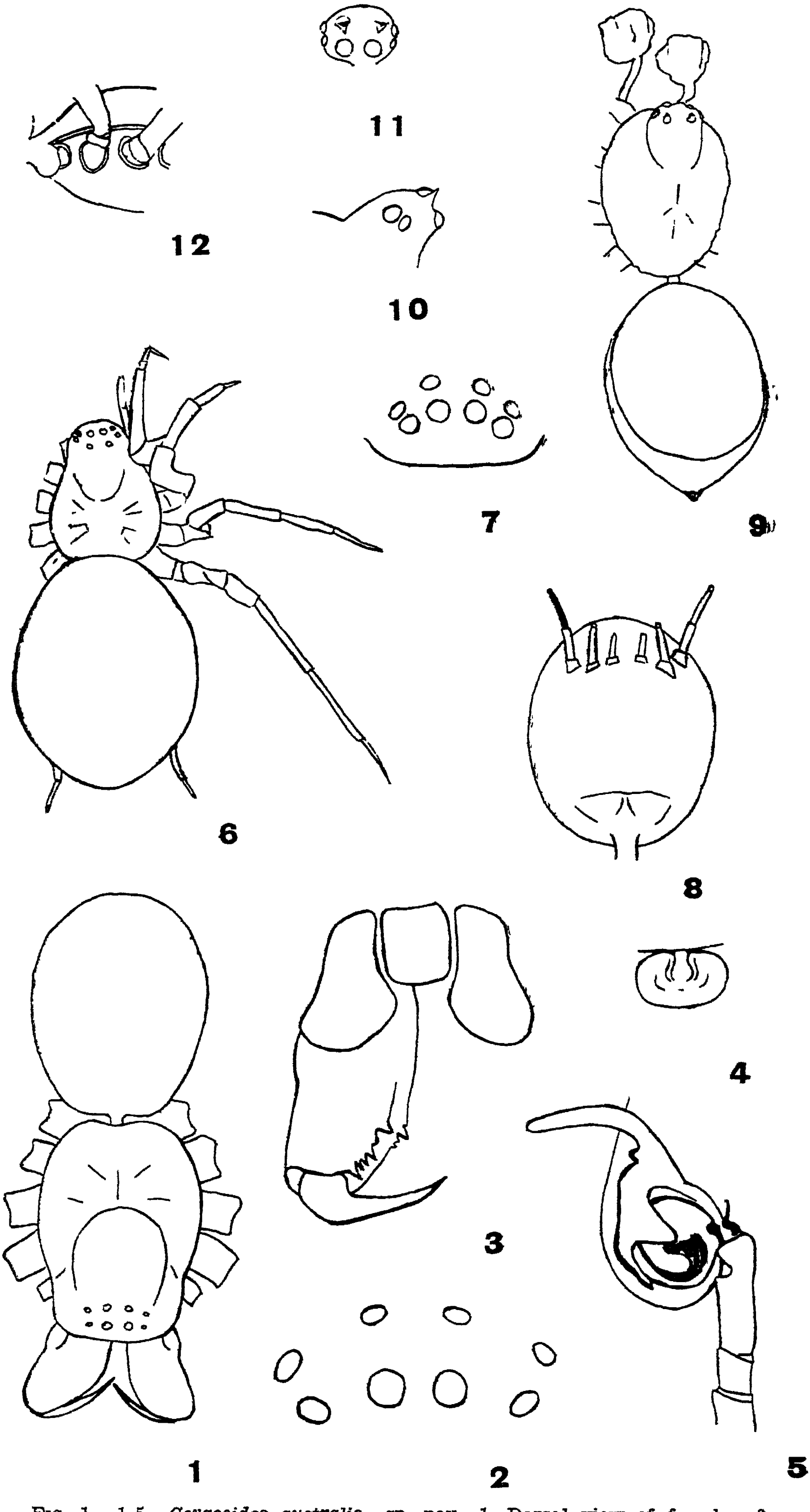

FIG. 1.—1-5, *Corasoides australis*, sp. nov. 1, Dorsal view of female. 2, Eyes of female, viewed from the front. 3, Chelicera, endites, and labium of female. 4, Epigynum of female. 5, Tarsal bulb of male. 6-8, *Neoavo a insolens*, sp. nov. 6, Dorsal view of female. 7, Eyes viewed from the front. 8, Ventral view of abdomen. 9-12, *Sternodes foraminatus*, sp. nov. 9, Dorsal view of female. 10, Eyes, lateral view. 11, Eyes, front view. 12, Posterior end of sternum, lateral view.

Superior margin, four teeth, scattered; inferior margin, six teeth, straight. Claw strong.

Labium.—Free, longer than broad, scopulated.

Endites.—Longer than broad, tapering to rear, broad and well curved in front, inner margins scopulated, outer curve has a serrula. This is not easily seen unless prepared for a microscopic mount in Canada balsam.

Sternum.—Broad as long, front square, broad, at the posterior end is a point.

Pedipalps.—Ending in a pectinated claw, well clothed with hairs and spines, especially on the tarsi.

Legs.—Long and strong, tarsi have three claws, inferior claw has a few teeth, superior claws well shaped with an even row of teeth. Tarsi no spines, other joints heavy spines present, especially the metatarsi and tibia. Formula, 1.4.2.3.

Leg.	Coxa.	Trochanter and Femur.	Patella and Tibia.	Metatarsus and Tarsus.	Total length.
1	2.1	7.2	8.8	9.0	27.1
2	2.0	6.0	6.0	6.9	20.9
3	1.8	6.8	4.8	6.2	19.6
4	2.1	6.9	7.5	9.0	25.5
Pedipalp . . .	1.0	4.0	3.2	Tarsus 2.8	11.0

Abdomen.—Obovate.

Epigynum.—Convex, oval, the long axis placed transversely, two lines of chitin form the central pattern at the top of which is a cream marking.

Spinnerets.—Anterior pair short and thick, the posterior slightly longer with the ends curving inwards, the medians are short and are hidden.

Colour in Alcohol.—Cephalothorax yellow fawn with grey markings, margins brown. Legs yellow fawn. Chelicera dark brown, boss paler. Abdomen with a black band half the width of the body situated on the dorsal part; this band has cream spots on the outer margin and a faint stripe in the centre. Sides grey. Ventral surface has grey margins; from the epigastric furrow to a position in front of the spinnerets is a rectangular pattern of cream with two grey stripes.

Male.

A little more slender than the female; other than the generative organs, the descriptions are nearly parallel.

Epigynum.—The presence of a few hairs on the centre of the anterior margin of the epigastric furrow is the only detail visible.

Pedipalps.—The cymbium has a lengthy prolongation equal to the length of its base. The ejaculatory duct is almost as long as the cymbium with its prolongation; it sweeps around the cymbium in a long curve, tapering off to a very long fine point.

Localities.—Cheltenham, near the Benevolent Home, 12.4.25.

Waddy Point, near Bark Hill Farm, on the shores of Lake Victoria, twelve miles from Bairnsdale, Victoria, 10.1.29. Type locality, Cheltenham.

Field Notes.—The webs of this spider can be found among low-growing bushes and grass growing in sandy soil. About nine inches from the ground attached to the grass and other objects is a mass of guy ropes, spun in all and every direction. This forms the upper portion of the web. This entanglement retards the flight of insects, which fall into a delicately woven sheet, spun parallel to the ground. The sheet, which measures eight inches by three inches, takes a turn at one end. It is at this position the occupant generally lurks. After the turn the sheet takes the form of a funnel shape, which tapers down to a tube and enters an underground burrow. The silk in this tube is of an uncommon weave. To the naked eye it is similar to muslin, having a definite weft and warp at right angles to each other; under magnification it becomes irregular, owing to an overlapping of its layers. One of these layers isolated exhibits a true square mesh of a width of 0·8 mm. The burrow is five inches in depth, and is partially lined with silk.

The female collected near Bairnsdale in January was dug out of its burrow; a cavity was excavated at one side of the tube, and here the spider was found guarding two egg-bags. They measured 14 and 12 mm. in diameter, and are dark in colour, owing to the presence of sand grains woven in the outer layer.

Sub-family HAHNIINAE.

Genus **Neoaviola**, nov.

Cephalothorax oval, slightly constricted and blunted in front. Head convex, cervical groove procurved. Eyes eight, separated, in two procurved rows, the posterior row more strongly procurved. A.M.E. largest. Spinnerets in a transverse row closely resembling the genus *Aviola*.

NEOAVIOLA INSOLENS, gen. et sp. nov.

(Text-fig. 1, Nos. 6-8.)

Female.

Total length, 1·72 mm. Length of cephalothorax to overhang of abdomen, 0·64 mm. Breadth of cephalothorax, 0·56 mm. Length of abdomen, 1·08 mm. Breadth of abdomen, 0·91 mm.

Cephalothorax.—Oval, slightly constricted and blunted in front. Head convex, well raised above the thorax, the front and sides slope abruptly to the outer margin, the posterior slope being less accentuated, cervical groove strongly procurved. Thorax broad, slightly convex. A few hairs are present on the head.

Eyes.—Eight, separated. Viewed from the front they are in two procurved rows, the posterior row more strongly so. A.M.E. largest, spherical, dark in colour, others elliptical, with a reflec-

tion from the tapetum giving them a bluish pearl-like colour. A.M.E. 0·05 mm. P.M.E. 0·05×0·037 mm. A.L.E. 0·05×0·031 mm. P.L.E. 0·05×0.29 mm.

Chelicera.—Small, weak, sloping down abruptly from the clypeus.

Labium.—Free, short, broader than long.

Endites.—Broader than long, curving inwards around the labium; at this point the corner is blunted and black in colour.

Sternum.—Convex, slightly broader than long.

Pedipalps.—Short, weak, sparsely clothed with thick hairs.

Legs.—Sparsely clothed with thick hairs. The three claws are not pectinated. Formula 4.1.2.3.

Leg.	Coxa.	Trochanter and Femur.	Patella and Tibia.	Metatarsus and Tarsus.	Total length.
1	0.2	0.54	0.5	0.53	1.77
2	0.19	0.48	0.47	0.6	1.74
3	0.2	0.48	0.46	0.58	1.72
4	0 21	0.7	0.58	0.8	2.29

Abdomen.—Obovate, slightly overhanging the cephalothorax.

Epigynum.—The rich brown of the chitin is conspicuous, but the shape and detail are indefinite.

Spinnerets.—Well separated in a broad, nearly straight line. All have a definite base, median and anterior single jointed, posterior two joints. Relative lengths, posterior (outer) 0·35 mm., anterior (intermediate) 0·21 mm., median 0·15 mm.

Colour in Alcohol.—Cephalothorax, dull yellow brown; the clypeus and the sectors between the radial striae are darker. Legs, pedipalps and sternum, dark grey with light fawn. Abdomen dark grey with yellowish spots; on the dorsum these spots form four letter Vs, with the apexes pointing forwards.

Type Locality.—Whittlesea, at the base of the hill leading to Kinglake, about 25 miles from Melbourne, September, 1927.

Field Notes.—Habits unknown; collected by shaking shrubs into an umbrella.

The male is unknown.

Family ARCHAEIDAE.

Sub-family ARCHAEINAE.

Genus **Archaea** C. Koch.

(in Berendt, *Organ. Reste in Bernst.*, i., 1854.)

ARCHAEA HICKMANI, sp. nov.

(Text-Fig. 2, Nos. 1-5.)

Female.

Total length, 3·0 mm. Length of head, 0·95 mm. Breadth of head, 0·7 mm. Length of chelicera, 1·6 mm. Breadth of cheli-

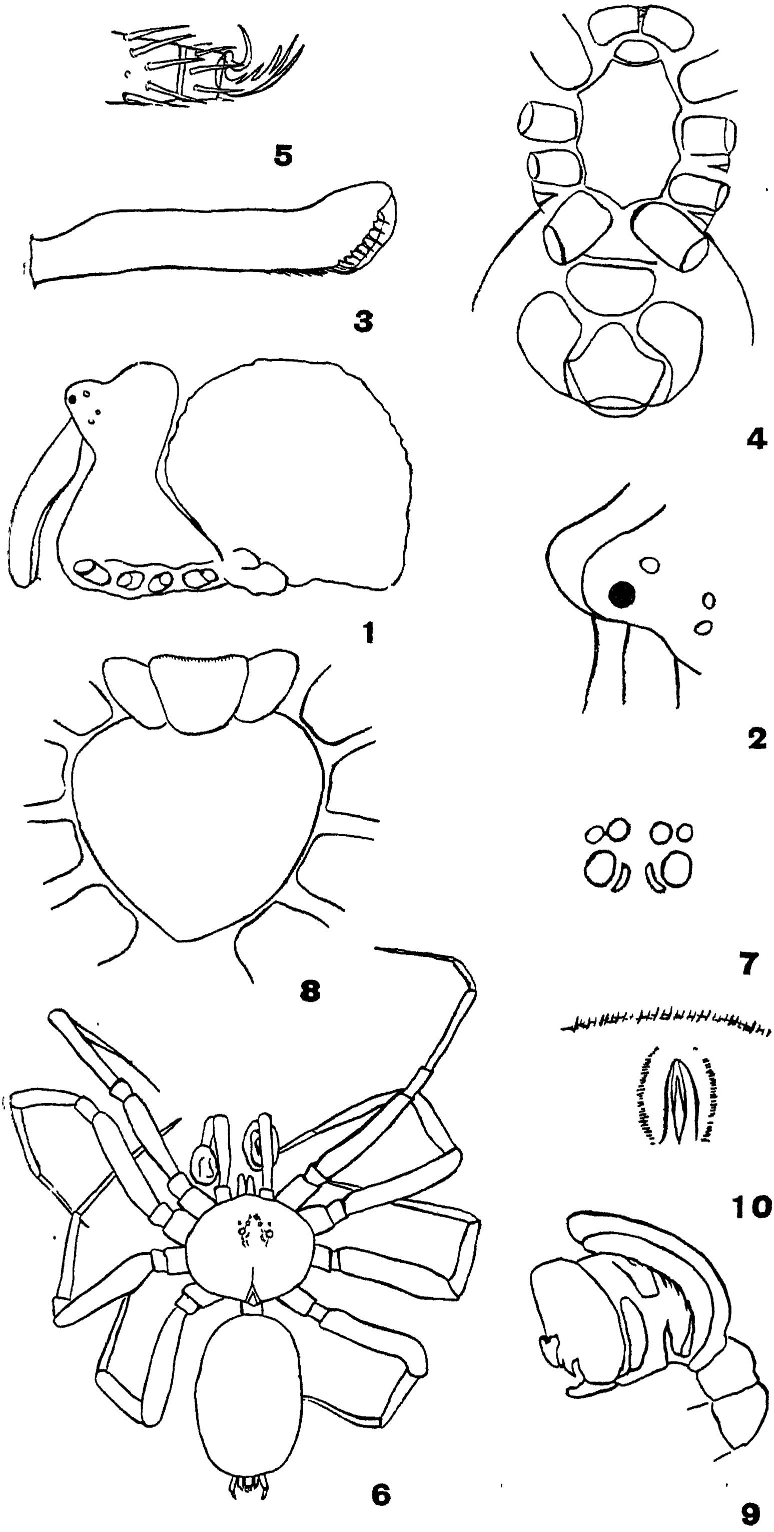

FIG. 2.—1-5, *Archaea hickmani*, sp. nov. 1, Lateral view of female with legs truncated. 2, Eyes, lateral view. 3, Chelicera. 4, Ventral view of female. 5, Tarsi, showing three claws.
6-10, *Oecobius navus* Blackw. 6, Dorsal view of male. 7, Eyes, viewed from above. 8, Sternum, and mouth parts. 9, Tarsal bulb of male. 10, Epigynum of female.

cera at widest part, 0·28 mm. Length of claw of the chelicera, 0·35 mm. Length of abdomen, 2·0 mm. Breadth of abdomen, 1·45 mm.

Cephalothorax.—Thorax short, broad, convex. Head elevated abruptly above, joined by a thick neck, head has an erect attitude, top of head highly arched. Forehead has a convex protuberance each side. Fawn colour hairs are spaced evenly over the carapace.

Eyes.—Eight, placed in two somewhat rectangular groups of four, each side of head. A.M.E. largest, on small tubercles, dark colour. Others reflect light as a golden colour from tapetum. A.M.E. 0·08 mm. P.M.E. 0·065 mm. A.L.E. 0·04 mm. P.L.E. 0·04 mm. Width between eyes.—A.M.E. 0·4 mm. P.M.E. and P.L.E. 0·15 mm. A.M.E. and A.L.E. 0·21 mm. A.M.E. and P.M.E. 0·06 mm. A.L.E. and P.L.E. 0·05 mm.

Chelicera.—Very long, robust, inner margin heavily spined near claw. Claw curved, end curving abruptly inwards.

Labium.—Short, set at right angles to sternum.

Endites.—Lightly scopulated; on the upper side in the centre is a short, cylindrical process; the coxa of the pedipalp joins this process.

Sternum.—Longer than broad.

Epimera.—Taper to a point between the coxae of the legs, posterior epimera longer.

Pedipalps.—Short, claw wanting.

Legs.—Formula 1.4.2.3. Three claws, major 0·05 mm., minor 0·02 mm., major claws, with three teeth, first tooth very long, third very short, second tooth an even graduation between the two. Hairs on tarsi have small serrations.

Leg.	Coxa.	Trochanter and Femur.	Patella and Tibia.	Metatarsus and Tarsus.	Total length.
1	0.4	1.85	2.0	1.0	5.25
2	0.3	1.4	1.4	0.8	3.9
3	0.25	1.25	1.1	0.9	3.5
4	0.3	1.7	1.45	1.1	4.55

Abdomen.—Globular, tapering to a blunted point at spinnerets, cuticle rugose. Book-lung plates anterior end semi-circular, taper to a point at rear curving inwards.

Epigynum.—Convex plate, widens out at half its length; it is then abruptly pinched in, tapers to a blunted end in front. The opening at the posterior end is edged on each side with a half-round edging.

Spinnerets.—Rosette shape, anterior 2 mm. long.

Colour in Alcohol.—Cephalothorax, chelicera and legs, brown, with darker markings. Abdomen light and dull fawn.

Locality.—Victoria, date about 1922. Unfortunately this is the only information available.

Field Notes.—No information available. It will be of interest

to note that Hewitt (5, p. 202) records that the South African species was found under stones in the damp bush, along with other creatures as land crustaceans, molluscs and peripatus.

The male is unknown.

This species is dedicated to the Tasmanian Arachnologist, V. V. Hickman, B.A., B.Sc., to whose assistance the writer is greatly indebted.

Family OECOBIIDAE.

Genus **Oecobius** Lucas.

(*Expl. Alg., Ar.*, 1845-48, p. 101.)

OECOBIUS NAVUS Blackwall.

(Text-Fig. 2, Nos. 6-10.)

Oecobius navus Blackwall, Ann. Mag. Nat. Hist., iv. (3), 1859, p. 266. Simon, Hist. Nat. des Araignées, i., 1892, p. 264. Rainbow, Rec. Austr. Mus., vi. (1), 1905, p. 11. Butler, Vic. Nat., xlii., Dec., 1925, pp. 208-9, 1 pl.

Female.

Total length, 2·75 mm. Length of cephalothorax, 0·9 mm. Breadth of cephalothorax, 1·1 mm. Length of abdomen, 1·85 mm. Breadth of abdomen, 1·5 mm.

Cephalothorax.—Oval, convex, broader than long, pointed front and rear. Ocular area central, elevated; a few coarse hairs are present nearby.

Eyes.—Eight, in two rows of four, anterior row slightly recurved, posterior row procurved, P.M.E. crescent shape with blunted ends, others circular, all evenly spaced. A.M.E., 0·06 mm. P.M.E. elongated, 0·09×0·03 mm. A.L.E. 0·04 mm. P.L.E., 0·085 mm.

Chelicera.—Cylindrical, tapering, claw evenly curved.

Labium.—Flat, broader than long, narrowed at rear, with blunted corners.

Endites.—Overlap on to the sternum.

Pedipalps.—Short, robust, ending with a pactinated claw.

Sternum.—Cordate, sparsely clothed with dark hair.

Legs.—Medium length, three claws all pectinated. Formula, 4.1.3.2.

Leg.	Coxa.	Trochanter and Femur.	Patella and Tibia.	Metatarsus and Tarsus.	Total length.
1	0.3	1.0	0.9	1.1	3.3
2	0.3	1.0	0.9	1.0	3.2
3	0.25	1.0	0.9	1.1	3.25
4	0.2	1.0	1.0	1.15	3.35
Pedipalp . . .	0.1	0.4	0.3	Tarsus 0.3	1.1

Calamistrum.—Half the length of the metatarsus.

Abdomen.—Obovate, sparsely clothed with hairs. Epigastric furrow faintly marked.

Epigynum.—Flat, inside a central depression, a thin, flat, pointed process protects the genital aperture. The whole is isolated from the epigastric furrow, the chitin is pale brown.

Spinnerets.—Visible from above; posterior with two articulations, the last joint curves inwards with short spinning tubes on the inner surface. Length: posterior, 1 5 mm., anterior 0·4 mm., median 0·1 mm.

Cribellum.—Undivided, anterior edge procurved, bordered with a thin chitinous line, marked with a central notch.

Anus.—Placed between the posterior spinnerets, it is a short cylindical column with a flat oval top, bordered with a palisade of long, evenly-spaced hairs. These hairs have a sharp bend outwards at a position of half of their length.

Colour in Alcohol.—Cephalothorax glossy, fawn with light grey markings, a large V shape marking of black almost hides the eyes. Legs and sternum pale yellow-fawn. Abdomen pale yellow-fawn, marked with black and white, forming a variable pattern. White spots are visible on the underside of the abdomen.

Male.

This corresponds to the female in nearly all the detail other than the reproductive organs. The calamistrium cannot be found. If it does exist it must be poorly developed. Cribellum visible, but not so well marked.

Epigynum.—Has no external markings.

Tarsal Bulb.—Has the simple spoon-shaped cymbium, with a very small development of the paracymbium. The genital bulb appears to have three divisions, superficially somewhat similar to the bulb of the genus *Linyphia,* which is of a simple type of the specialised form of palp.

Localities in Australia.—Sydney, Adelaide (collected by Dr. R. H. Pulliene), and Melbourne.

Habitat.—As its name implies, it is a house dweller. Its home is a thin, almost invisible, sheet, about one inch in size, spun over small depressions or in the angles of the walls of houses; this web is more conspicuous when old and covered with dust.

Family PALPIMANIDAE.

Sub-family HERMIPPINAE.

Genus **Sternodes**, nov.

Eyes eight, in two recurved rows, A.M.E. largest. Head elevated. Three claws, inferior claw very small. Male tarsi large, globular. Sternum completely surrounds the coxae of each leg. Labium small, attached to a small extension of the sternum. Scopulae on the tarsi are wanting.

STERNODES FORAMINATUS, gen. et sp. nov.

(Text-Fig. 1, Nos. 9-12.)

Male.

Total length, including spinnerets, 2·83 mm. Length of cephalothorax, 1·28 mm. Breadth of cephalothorax, 0 96 mm. Length of pedicel, 0·04 mm. Length of abdomen, 1·38 mm. Breadth of abdomen, 1·1 mm. Length of spinnerets, 0·13 mm.

Cephalothorax.—Convex, oval, broad in front, tapers at rear. Clypeus vertical, wide. Head elevated. Ocular area projecting sharply forward, and upwards. Thorax sloping abruptly at rear. Carapace slightly rugose.

Eyes.—Eight, anterior row recurved, posterior row recurved less. A.M.E. largest, dark colour, all others are pearl like in colour, laterals close together, elliptical. A small prominent spine projects forward in front of the P.M. Eyes. A.M.E. spherical, 0·11 mm. P.M.E. spherical, 0·08 mm. A.L.E. elliptical, 0·08×0·06 mm. P.L.E. elliptical, 0·10×0·08 mm.

Chelicera.—Follows the same plane as the clypeus, it is short and tapers to the claw, which is small and curved.

Labium.—Triangular, attached to a small extension of the sternum.

Endites.—Small, curving inwards, lightly scopulated.

Sternum.—Longer than broad, slightly rugose. The coxa of each leg is completely surrounded by the extensions of the sternum, the upper margin of the sternum meets the margin of the dorsal carapace in a parallel line.

Pedipalps.—Short, coxae and trochanter thin, other joints thicker. Tarsal bulb large, spherical, on which complex detail is visible. Cymbium broad, hemispherical. Ejaculatory duct very short.

Legs.—Medium length. Coxae cylindrical, with a slight taper at each end. Three claws are present; the superior pair are dentated with an even row of long teeth, all of which are even in length with the claw. Inferior claw smooth, small. Tarsi are devoid of scopulae. Formula 1.2.4.3.

Leg.	Coxa.	Trochanter and Femur.	Patella and Tibia.	Metatarsus and Tarsus.	Total length.
1	0.36	1.25	1.36	1.0	3.97
2	0.32	1.12	1.04	1.16	3.64
3	0.24	0.88	0.92	0.8	2.84
4	0.24	1.08	1.16	1.12	3.6

Abdomen.—Obovate, dorsum covered half the length with a translucent chitinous plate. The ventral side is covered in a similar manner. This plate is connected with the pedicel. In the centre of the ventral plate is the epigastric furrow, and

over the book lungs are furrows. At the posterior end of the abdomen, a chitinous ring encircles the spinnerets, colulus, and the anus.

Epigynum.—Double convex opening.

Spinnerets.—Visible from above, short, inferior conical, superior cylindrical, medians appear to be missing; it would be necessary to dissect the only specimen to definitely prove this. A small colulus is present.

Colour in Alcohol.—Cephalothorax, chelicera, dorsal and ventral plates of the abdomen, a rich brown, legs slightly paler. The integument of the abdomen is cream in colour with pale grey markings.

Type Locality.—Whittlesea, at the base of the hill leading to Kinglake, about twenty miles from Melbourne. Date of collecting, September, 1927.

Field Notes.—Habits unknown; collected by shaking shrubs into an umbrella.

The female is unknown.

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[Proc. Roy. Soc. Victoria, 42 (N.S.), Pt. I., 1929.]

Art. VII.—*Notes on Coptotermes bornensis Oshima (Isoptera). A Study in Description of the Termite Soldier.*

By A. C. DAVIS.

[Read 11th July, 1929; issued separately 30th October, 1929.]

Termitologists have long felt the need of a more satisfactory method of determining and expressing the characters of the soldiers of termite species. Experience of students of the group, written and orally expressed, has been accumulating to show that the general part of most descriptions of species, and especially of the soldiers, deals mainly with generic characters, or characters common to numerous species, with characters of an extremely variable nature, or with characters of a nature such as to prevent their clear expression in words, and that with few exceptions the characters of practical importance in differentiating species are those of shape, size, and proportions of hard parts, chiefly the head, mandibles, gula, fontanel, pronotum, and perhaps the labrum and leg segments. Characters of proportion lend themselves to a mathematical expression (Light, 1927). Characters of shape call for a certain amount of description in words, and demand illustrations to overcome the limitations of language, yet they also may all be expressed in part, at least, by indices of relative proportions.

Since, therefore, the characters of practical importance in such work depend upon measurements, it becomes of primary importance, if these measurements and the values derived therefrom are to be helpful and not actually misleading, that the terms applied to dimensions of parts be accurately defined, and that these definitions be given in unmistakable form by all workers in the field until some general agreement has been arrived at. The importance of this point cannot be over-emphasized, and Light (1921) and Emerson (1925) have set a precedent in this regard which must be followed by all workers in the field if confusion and error are to be avoided.

Further, there has often been an unfortunate lack of diagnoses and even of comparisons with closely related species in papers on termite systematics which has rendered all the more difficult the work of those who followed after. Such diagnoses and comparisons of species give the real reasons for the erection of the species, reasons which are often quite lost in the ordinary description.

In a recent paper Light (1927) has called attention to these conditions, and proposed the extensive use of indices of proportions of parts as the only means of putting the systematics of the group on a workable basis. At the suggestion of Dr. Light I

have attempted a redescription of *Coptotermes bornensis* Oshima with the above points in mind. An attempt has been made to eliminate extraneous elements from the description, and yet to give all the material available for systematic purposes at this time. Following the description is an attempt at a criticism of the original description in the light of the newer methods exemplified. *Coptotermes bornensis* was chosen because paratypes of this species presented by Dr. Oshima were available in the collection of Dr. Light, thus making possible a redescription. Any one of a number of descriptions by any one of several authors might have been chosen to point the moral.

Methods.

Measurements were made from both alcoholic and mounted specimens. The latter give greater accuracy, but unmounted specimens if carefully oriented allow for sufficiently accurate measurement. When mounts were made mouth-parts and gula were dissected out and mounted with the head.

A method of embedding in celloidin, for which I am indebted to Mr. Albert E. Galigher, of Berkeley, California, is extremely well suited to this type of work, and directions for its use follow.

The parts to be mounted, dissected out in alcohol under the binocular dissecting microscope, are placed in a small, flat-bottomed dish, such as a Syracuse watch-glass or a two-inch Petri dish. Drain off the excess alcohol and pour in enough 2% celloidin to cover them. They may then be arranged as desired. If the celloidin should become too hard before this is accomplished, two or three drops of ether-alcohol may be poured over the objects. This will soften the celloidin in that region, and allow for further manipulation. The objects having been arranged, the celloidin is allowed to harden on top, and a little chloroform poured into the dish and allowed to stand for some time. This hardens the celloidin sufficiently so that a sheet of the desired size may be trimmed out and transferred to carbol-xylol to clear. It is then placed in xylol for a few minutes, put on a slide with balsam, and covered. Mounts of this sort are permanent, and the objects are fixed in position, with no possibility of their tipping or getting out of arrangement.

All examinations were made under very low powers of the compound microscope, and measurements were made by means of an ocular micrometer scale. Drawings were made with a projection apparatus, except that of the side view of the head, for which material for an extra mount could not be sacrificed, and which was therefore drawn to the same scale with a camera lucida.

Measurements and Values.

The characters of the dimensions of the fontanel aperture and the angle of inclination have not heretofore been used. In some

species they may be so nearly the same as to be valueless, yet in many cases, as in the present, these two characters do have a definite value in diagnosis. In measuring the angle of inclination, the head is placed upon its side, and an ocular protractor or goniometer is used. The base line is set from the lower edge of the fontanel to the most posterior point of the head. In most cases this will closely parallel the dorsal profile. The angle of inclination from the vertical may then be easily measured. The dimensions of the fontanel aperture are measured with an ocular micrometer, the head being at the proper angle to bring the fontanel rim on a level all round.

The fontanel index as defined by Light (1921) has not been used since, as pointed out by him (1927), it presents certain difficulties of measurement for the *Coptotermes* soldier, and, due to the large size and inclination of the fontanel aperture, really involves two variable factors, the relative location of the fontanel and degree of inclination of its aperture. It will doubtless prove of great value in other genera possessed of a small fontanel.

The fontanel aperture index, hereafter referred to as aperture index, as used here, is the fractional result of dividing the average maximum fontanel length (longitudinal or vertical diameter of the fontanel aperture) by its average maximum breadth (transverse diameter). The aperture, which shows white in contrast to the darker margin, alone is measured.

The length of the left mandible is measured in dorsal view, from the posterior margin of the condyle in a straight line to the apex of the mandible.

The pronotal index is the average maximum breadth divided by the average of average minimum and average maximum length.

All other measurements are as defined by Light (1927), and values are derived as follows:—

Head index=Maximum breadth divided by length.

Head contraction index=Minimum breadth divided by maximum breadth.

Gular index=Gular length divided by average gular breadth.

Gular contraction index=Minimum breadth divided by maximum breadth.

Gular maximum breadth index=Gular length divided by maximum breadth.

Gular minimum breadth index=Gular length divided by minimum breadth.

Pronotal index=Maximum breadth divided by average length.

Light (1927) has shown the most significant of these to be head contraction index and gular contraction index.

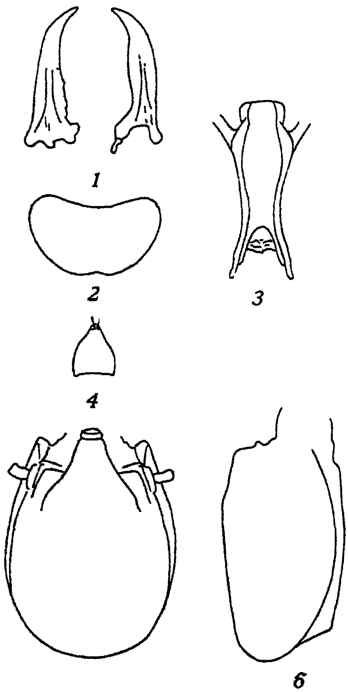
COPTOTERMES BORNENSIS Oshima.

C. bornensis Oshima, 1914, Annot. Zool. Japaneses. vii., pp. 556-7, pl. ix., fig. 2.

Diagnosis.

Alate unknown.

Soldier.—Of medium size for the genus, head averaging 1·25 mm. in length and 1·03 in maximum width; head contraction index 0·68; fontanel distinctly tubular and extending beyond the level of the anterior angles of the head, i.e., fontanel index 1+; fontanel aperture small (0·089×0·096 mm.), nearly round, aperture index ca. 0·93; very nearly upright with an inclination of but 2°-5° from the vertical; right mandible thickened in middle third; gular index 2·58; contraction index 0·51; maximum breadth index 1·95; minimum breadth index 3·8, pronotal index 2·14.



FIGS. 1—6. *Coptotermes bornensis* Oshima ×24.

1. Mandibles, dorsal view; 2. Pronotum; 3. Gula, ventral view; 4. Labrum, dorsal view; 5. Head capsule, dorsal view; 6. Profile of head.

Description.

Soldier.—Colour as usual for the genus.

Vestiture of large and small, stiff white hairs. A few scattered erect bristles on head; dorsal sclerites with rather dense pubescence, the larger hairs arranged in a row along the posterior margin of each, and a second incomplete, irregular row within; smaller hairs scattered irregularly over the disc. Pubescence finer and more dense posteriorly.

Head is of the shape shown in Fig. 5, oval in dorsal outline, sides converging anteriorly. Fontanel tubular, the tube starting well back on the head, and the sides converging anteriorly to form the heavy chitinous border of the fontanel, terminating approximately 0·1 mm. anterior to the anterior angles of the head; fontanel aperture nearly round, and directed forward at an angle of from 2 to 5 degrees from the vertical. Chitinous upper rim of the antennal fovea heavy and thick, prominent posteriorly, less so anteriorly. Within this and median to it runs a parallel ridge, interrupted just forward of the anterior edge of the fovea, then turning inward at about a right angle to parallel the mandibular articulation for a short distance; median to this ridge a second, smaller ridge, subparallel to it (Fig. 5).

Antennae, 13-jointed in the specimens studied; second joint cylindrical, nearly square in outline as viewed from the side, smaller in diameter, and half as long as the first; third joint, in specimens examined, equal to the second in length, but somewhat pear-shaped.; fourth joint subequal to or shorter than the second, pear-shaped, the small end basal, widest at the apical third. Joints 5-8, increasing successively in size, pear-shaped, pedunculate, ("stem" end basal); joints 9, 10 and 11 equal in length to 8; joint 12 somewhat longer, 13 subequal to 12, but smaller in diameter, subovate, and widest at the basal third.

Labrum of the shape shown in Fig. 4; hyaline tip distinct, colorless, triangular in dorsal view, with a rounded apex.

Left mandible sharp, curved at the tip, dark mahogany brown or blackish in colour; denticulation amounting to little more than crenulation, three very small teeth and a large basal tooth (Fig. 1). Right mandible untoothed, very characteristic in shape, somewhat shorter, blunter, and less curved at the apex than left mandible; inner cutting edge of the mandible swollen just back of the apex (Fig. 1).

Gula with somewhat globular anterior portion (Fig. 3).

Pronotum (Fig. 2) with the anterior margin broadly, concavely arcuate; antero-lateral angles broadly, evenly rounded; postero-lateral and posterior margins are smoothly, evenly rounded, a very slight, obtuse emargination in the mid-line.

MEASUREMENTS AND INDICES.

	Indices	Maximum	Minimum	Average
Head				
length with mandibles	—	—	—	1·964
length	—	1·327	1·181	1·256
length to fontanel	—	1·341	1·245	1·293
maximum breadth	—	1·038	1·009	1·026
minimum breadth	—	0·717	0·687	0·702
index	0·818	—	—	—
contraction index	0·684	—	—	—
Gula				
length	—	0·750	0·718	0·734
maximum breadth	—	0·392	0·356	0·377
minimum breadth	—	0·199	0·190	0·193
average breadth	0·260	—	—	—
index	2·576	—	—	—
contraction index	0·512	—	—	—
maximum breadth index	1·947	—	—	—
minimum breadth index	3·803	—	—	—
Head length divided by				
maximum gular breadth	3·332	—	—	—
minimum gular breadth	6·508	—	—	—
average gular breadth	4·407	—	—	—
gular length	1·711	—	—	—
Fontanel				
length	—	0·095	0·078	0·089
breadth	—	0·099	0·094	0·096
angle of inclination	2°–5°	—	—	—
aperture index	0·927	—	—	—
Labrum				
length	—	—	—	0·293
length with hyaline tip	—	0·313	0·240	0·276
maximum breadth	—	0·258	0·223	0·240
Pronotum				
maximum length	—	0·383	0·351	0·367
minimum length	—	0·303	0·287	0·295
maximum breadth	—	0·731	0·703	0·717
index	2·140	—	—	—
Length of hind tibia	—	0·783	0·750	0·767
Length of left mandible	—	0·894	0·846	0·863
Total length of insect	—	3·8	3·6	3·7
Length of antenna	—	1·229	0·958	1·091

Description drawn from three soldiers collected by Mr. Ryozo Kanehira at Balik-Papan, Dutch Borneo, April 20, 1913. These specimens, paratypes from Oshima's type material, are in the collection of Dr. Light, No. 330B.

The averages given are the averages of the three specimens. Maximum is the largest measurement of the particular part, and the minimum the smallest. The only exception is the average gular length, which is the average of the average minimum and average maximum lengths.

The foregoing description, while by no means complete, includes all of the points covered in the original, with some additional information, yet if the measurements were not included, I very much doubt that anyone could identify the species from

it with any degree of certainty. Color is unsafe to depend upon. Vestiture may vary considerably, and has not been well described by many termitologists. The antennal characters, while apparently thought much of, are subject to so much variation as to be virtually useless. The number of segments and their relative size in the region of the third joint differ between individuals of the same colony. The same objection applies to body length in even greater degree, since this is subject to fluctuation according to the amount eaten, loss of cephalic gland secretion, etc. It will be seen, then, that the general facies of the termite soldier is not a safe guide to diagnosis. There remain the shape of the head, pronotum, mandibles, and gula, and the proportional measurements, and these are the essential parts of the description. The labrum is of minor importance, its significance not having been worked out, but the measurements may be useful in some cases.

In addition to all the above difficulties, the usual description is couched in such vague terms as to make identification extremely difficult. For example, to quote Oshima: "Head oval, vaulted dorsally, . . . fontanelle directed forward." In dorsal view the head is oval enough to allow the use of this term. When viewed from either end the head is evenly rounded dorsally, perhaps enough to merit the term vaulted. In profile, however, the head is decidedly flattened dorsally, as shown in the figure. "Fontanelle directed forward" is true enough, but means little. The fontanel is directed forward and the dorsal edge of it is 0·1 mm. in advance of the antero-lateral angles of the head, as will be seen from the measurements. The tube-like process of the fontanel is rather peculiar, being conspicuous and terminating in a little separate margin for the orifice. The angle of inclination is also characteristic. "Pronotum slightly longer than one-half the width, anterior border strongly indented at the middle, posterior border slightly emarginate at middle. . . . The term "indented" means little. I take it that this means that the anterior margin is slightly, obtusely emarginate, at the mid-line, but there is nothing to indicate that this is the case. It might just as well mean the whole arcuate anterior margin. There is, in the specimens at hand, no perceptible emargination of the anterior margin. At the mid-line, however, there is an indentation of the dorsal surface that at first glance appears to involve the anterior margin, but actually does not do so. Perhaps it is to this that Oshima refers. The term "slightly emarginate" is correct, but the shape of the emargination is not specified. It might be rounded at the bottom, acute, or obtuse. Actually it is a slight, obtuse emargination, fairly sharp at the bottom.

The measurements of Oshima agree fairly closely with mine, except that the length of the pronotum is given as 0·41 mm. I have 0·295 mm. along the mid-line, and 0·367 mm. from the most posterior to the most anterior points. If Oshima has given the latter measurement the discrepancy is less, but I understand that

this is not the common practice, and he does not state which was used. In case the length along the mid-line is given, there must be some error in his measurements, as I have carefully checked mine.

A point that evidently escaped Oshima's notice is the peculiar shape of the right mandible, which appears to be characteristic of this species.

Oshima considers *Coptotermes travians* Haviland to be the most closely related of described *Coptotermes* species, the new species differing in a more contracted gular and in having but 13 antennal segments. Without the alates he felt it difficult to differentiate the two species. Yet a careful comparison shows distinguishing characters to abound, some of rather a striking nature. unusual in the genus, such as the tubular fontanel, very slight angle of inclination and swollen right mandible of *C. bornensis*. Others are brought out by the indices of proportions proposed by Light (1927) and used in the preceding description.

Below is given a comparative table showing in parallel columns the indices for *C. bornensis* and *C. travians*. Those for *C. bornensis* are based on measurements of but three specimens, and those for *C. travians* on measurements for but one from Singapore, identified by Holmgren, No. Si 365 in Dr. Light's collection. These are subject to considerable revision when more data are available. While the two species show a surprising correspondence in most of these indices, significant differences are to be noted, particularly in pronotal index, fontanel aperture index, and fontanel index.

	Coptotermes bornensis	Coptotermes travians
Head index	0·818	0·812
Head contraction index	0·684	0·622
Gular index	2·576	2·575
Gular contraction index	0·512	0·535
Maximum gular breadth index	1·947	1·976
Minimum gular breadth index	3·803	3·695
Pronotal index	2·140	1·980
Fontanel aperture index	0·927	0·874
Head length divided by—		
Maximum gular breadth	3·332	3·454
Minimum gular breadth	6·508	6·458
Average gular breadth	4·407	4·501
Gular length	1·711	1·747
Fontanel index	1 +	0·890

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[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. I., 1929.]

ART. VIII.—*Two New Species of Coptotermes Wasmann (Isoptera).*

By S. F. LIGHT and A. C. DAVIS.

[Read 11th July, 1929; issued separately 31st October, 1929].

This paper presents descriptions of two new species of *Coptotermes,* one from the Celebes and the other from the Solomon Islands. The method, recently proposed by the senior author (Light, 1927), of expressing characters of proportion in the form of indices justifies this addition to the already extensive list of *Coptotermes* species based on the soldier caste. It is believed that this method provides an exact and easily used means of differentiating such species and gives promise of resolving in great part the chaotic state of the taxonomy of certain termite genera.

The measurements and indices are those proposed by the senior author (Light, 1927). In addition the inclination of the fontanel and the fontanel aperture index are used as defined by the junior author (Davis, 1929).

COPTOTERMES FROGGATTI, sp. nov.

Diagnosis.

Alates unknown.

Soldier.—Head index, 0·79; head contraction index, 0·70; gular index, 2·46; gular contraction index, 0·629; maximum breadth index, 2·01; minimum breadth index, 3·19; fontanel aperture index, 0·639; angle of inclination, 29° to 31°; pronotal index, 2·00.

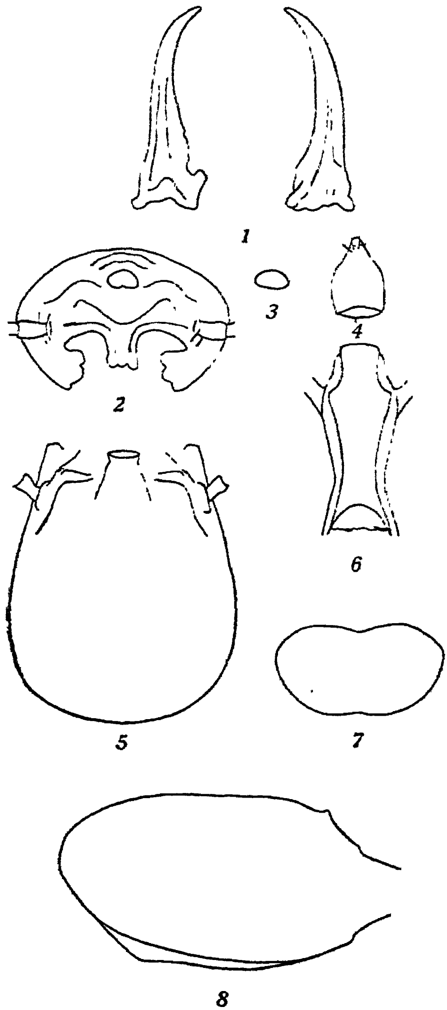
Description.

Soldier.—Head orange-yellow, darker along anterior margin, broadly rounded behind, widest at basal two-fifths, thence converging regularly to the articulation of the mandibles; evenly rounded when viewed from either end as in cross section, flattened dorsally as viewed in profile (Figs. 5 and 8). Fontanel prominent, aperture large, with a rather heavy rim of brown chitin, angle of inclination of from 29° to 31° from the vertical (Fig. 8). In about 85% of the specimens at hand the anterior (lower) margin of the aperture is raised in a small tooth in the mid-line, giving the opening a heart-shaped outline (Fig. 2). (This tooth is disregarded in measurements.) In the remainder the lower edge is straight (Fig. 3).

Mandibles red-brown or blackish, pointed, curved at tip, cutting edges smooth except near the base. Left mandible with

basal tooth conspicuous, quadrate, and with three or four minute denticles immediately anterior to it; right mandible lacking teeth (Fig. 1).

Labrum roundedly triangular, widest at about middle, two stiff, erect bristles at apex, dorsally. Hyaline tip distinct, rounded at apex (Fig. 4).



Figs. 1—8. *Coptotermes froggatti* sp. nov. × 24.

1. Mandibles, dorsal view; 2. Antero-dorsal view of head, showing location and usual shape of fontanel aperture; 3. Shape of fontanel aperture in the minority of specimens; 4. Labrum, dorsal view; 5. Head, dorsal view; 6. Gula, ventral view; 7. Pronotum, dorsal view; 8. Head, profile view.

Rim of each antennal fovea heavy, arising abruptly posteriorly, sloping inward anteriorly. Median to this, at its anterior fourth, a ridge arises, runs forward and medially to a point about two-fifths of the distance to the anterior angle of the head. There it is interrupted, turns inward at an angle of about 120°, and ends near the edge of the fontanel ridge. Immediately within this is another smaller ridge, the angle of which is less sharp, and which terminates posterior to the antennal fovea (Fig. 5).

The antennae of all specimens are broken, the longest being of but 13 joints. Basal joint about twice as long as wide, widest at anterior end, very slightly constricted at middle. Joint II about half the diameter and one-third the length of the basal joint, nearly square in profile. Joint III one-half the length of II and somewhat less in diameter. Joint IV equal to II in diameter, but somewhat shorter. Joint V equal to II in length. Joints VI and VII pear-shaped or round, longer and greater in diameter, remaining joints successively increasing in diameter.

Gula widest at anterior third, squarely truncate anteriorly, lateral angles very round, lateral rim wide (Fig. 6).

Pronotum pale creamy yellow, saddle-shaped, widest just behind the apical third. Anterior emargination shallow, usually round at bottom; anterior margin on each side broadly rounded to a rather sharp lateral angle, thence the margins converge in a regular curve to the posterior margin; posterior emargination almost non-existent, there being but a slight median sinuation (Fig. 7). Three or four long stiff bristles and a number of shorter ones dorsally on the anterior margin; a few stiff bristles near the posterior margin and scattered irregularly over the disc.

Meso and metathoracic segments dorsally with sparse bristles, especially toward the lateral margins.

Abdomen dirty white in color, first and second segments dorsally with several bristles on either side of the mid-line and a few on the sides; third with only three or four bristles near mid-line, but more at sides, succeeding segments to ninth with few or no hairs; ninth and terminal segments sparsely clothed with fine, posteriorly-pointing hairs. Styles conical, 3-jointed, with long bristles, especially on basal joint.

Described from 14 soldiers collected by W. W. Froggatt at Banika, Russel Group, Solomon Islands, April 13th, 1913, No. 89S in collection of senior author.

There are a number of workers present, but, as this is a mixed collection containing workers of at least two species, it is not thought wise to attempt to determine the worker of this species until more definite data can be obtained.

This species has been named for Mr. W. W. Froggatt, whose contributions to the classification of the termites, particularly those of Australia, are too well known to need recounting here.

Coptotermes froggatti seems most closely related to *C. acinaciformis* Froggatt of Northern Australia. The two species differ

significantly, among other points, in the shape of the gula and the head as brought out in the table below by their gular contraction indices and head contraction indices.

MEASUREMENTS AND INDICES.

(Of Soldiers of *Coptotermes froggatti*, sp. nov.).

	Indices	Measurements (in millimeters)		
		Maximum	Minimum	Average
Head				
length	—	1·613	1·557	1·581
length to fontanel	—	1·565	1·493	1·513
maximum breadth	—	1·294	1·198	1·256
minimum breadth	—	0·910	0·856	0·883
index	0·794	—	—	—
contraction index	0·703	—	—	—
Gula				
length	—	0·923	0·814	0·890
maximum breadth	—	0·463	0·415	0·443
minimum breadth	—	0·297	0·267	0·279
average breadth	0·361	—	—	—
index	2·46	—	—	—
contraction index	0·629	—	—	—
maximum breadth index	2·009	—	—	—
minimum breadth index	3·190	—	—	—
Head length divided by				
maximum gular breadth	3·568	—	—	—
minimum gular breadth	5·666	—	—	—
average gular breadth	4·380	—	—	—
gular length	1·776	—	—	—
Fontanel				
length	—	0·125	0·112	0·115
breadth	—	0·193	0·174	0·180
angle of inclination	29°–31°	—	—	—
aperture index	0·639	—	—	—
Labrum				
length	—	0·407	0·303	0·351
length with hyaline tip	—	0·439	0·335	0·384
maximum breadth	—	0·343	0·315	0·320
Pronotum				
maximum length	—	0·521	0·489	0·502
minimum length	—	0·473	0·431	0·456
maximum breadth	—	1·022	0·926	0·958
index	2·000	—	—	—
Length of hind tibia	—	1·159	1·089	1·118
Total length of insect	—	—	—	5·3

Indices of proportion are not available for the other *Coptotermes* species known from the Solomon Islands, but Snyder's measurements (Snyder, 1925) indicate that *C. froggatti* is considerably larger than *C. pamuae* Snyder and smaller than *C. grandiceps* Snyder and *C. solomonensis* Snyder. From *C. dobonicus*, a new Guinea species of somewhat the same size, *C. froggatti* shows numerous differences of proportion as brought out by the indices given below.

The question of the relationship of *C. froggatti* to the species described by Hill (1927) in his recent article on Termites from the Australian Region, received as this was ready for press, must rest until further data concerning these species are available or a comparison possible. *C. remotus* is unquestionably very different, its smaller size distinguishing it at once. So far as Hill's measurements indicate, *C. obiratus* Hill is nearer *C. froggatti* than is *C. solomonensis* Hill. The material on which *C. froggatti*, sp. nov. and *C. solomonensis* Hill are based was collected by Froggatt in the same islands of the Solomon group, thus establishing a probability of their being the same species. There is a decided difference in certain measurements, however, which makes it seem advisable to consider them distinct for the present. It seems quite possible that *C. solomonensis* Hill is synonymous with *C. pamuae* Snyder. If this is not true then *C. solomonensis* Hill must receive a new name, because of the priority of *C. solomonensis* Snyder. If *C. froggatti* proves to be separate we propose the name *C. hilli* for *C. solomonensis* Hill.

Had the authors known of Hill's paper, this paper would probably never have been written, but it would seem to present the necessary data to begin a revision of this tangle, and hence is presented for what it is worth.

	Northern Australia	Solomon Islands	N Guinea	Solomon Islands	Solomon Islands	Solomon Islands
	C. acinaciformis Froggatt	*C. froggatti* sp. nov.	*C. dobonicus* Oshima	*C. pamuae* Snyder	*C. solomonensis* Snyder	*C. grandiceps* Snyder
Head length	1·63	1·58	1·63	1·35	1·8	1·7
„ breadth	1·31	1·256	1·39	1·15–1·2	1·45	1·45
„ index	0·800	0·794	0·850	—	—	—
„ contraction index	0·604	0·703	0·686	—	—	—
Gular index	2·42	2·46	3·03	—	—	—
„ contraction index	0·564	0·629	0·520	—	—	—
„ max. breadth index	1·88	2·01	2·30	—	—	—
„ min. „ „	3·33	3·19	4·42	—	—	—
Pronotal length (min.)	—	0·456	0·524	0·45	0·6	0·5
„ „ (max.)	—	0·502	0·575	—	—	—
„ breadth	—	0·958	1·103	0·75	1·0	1·0
„ index	—	2·00	2·007	—	—	—
Fontanel length	—	0·115	0·143	—	—	—
„ breadth	—	0·180	0·162	—	—	—
„ aperture index	—	0·639	0·882	—	—	—
Angle of inclination	30°	29°–31°	35°	—	—	—

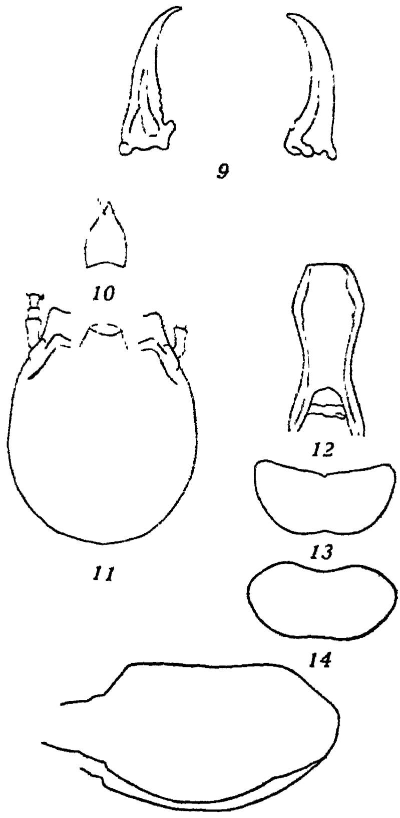
Coptotermes oshimai, sp. nov.

Diagnosis.

Alates unknown.

Soldier.—Head index, 0·895; head contraction index, 0·595; gular index, 2·305; gular contraction index, 0·633; maximum

breadth index, 1·880; minimum breadth index, 2 969; fontanel aperture index, 0·613; angle of inclination, 27°-34°; pronotal index, 3·245.



9 10 11 12 13 14 15

FIGS. 9—15. *Coptotermes oshimai*, sp. nov. ×24.

9. Mandibles, dorsal view; 10. Labrum, dorsal view; 11. Head, dorsal view; 12. Gula, ventral view; 13. Pronotum with anterior margin upturned against the head; 14. Normal pronotum; 15. Head, profile view.

Description.

Soldier.—Slender and elongate. Head yellow-brown, somewhat darker near anterior margin; antennal foveae rimmed with darker chitin; mandibles yellowish basally, dark brown to nearly black in apical two-thirds; remainder of the body light creamy with the exception of a yellowish anterior portion and a dark yellow anterior margin on the pronotum and light yellow patches in the antero-lateral regions of the meso- and metanota.

Head with a few erect hairs; pronotum with a few stiff, seta-like hairs on the anterior angles and along the posterior margin, and a number of fine hairs on the anterior and lateral margins; meso- and metanota with a number of seta-like hairs along the lateral and posterior margins, and a few scattered ones on the disc; remaining somites to the ninth sparsely clothed with stiff hairs, those on the posterior margins being about three times as long as the others, and arranged in one row along the margin and a second, incomplete row within; ventral sclerites even more heavily clothed; terminal sclerites with a great number of long, fine hairs, and a few longer stouter ones. This pubescence of the abdomen is very noticeable, even under a hand-lens.

Posterior half of head almost hemispherical as viewed from above, the posterior outline smoothly and evenly rounded; sides of the head nearly parallel for a short distance, from about the basal two-fifths to the distal two-fifths; anterior to this converging sharply to a point just anterior to the antennal insertion, and from this point anteriorly less sharply convergent, resulting in a concavely arcuate outline from the anterior angles to the distal two-fifths, as shown in Fig. 11. Head in side view flattened or stricted at the centre, somewhat wider distally; 2nd four-fifths as 15.)

Antennae 14-jointed, clavate; 1st joint cylindrical, slightly constricted at the centre, somewhat wider distally; 2nd four-fifths as wide as first, a little more than one-half as wide at base, two-thirds as wide at distal one-third; 4th subequal, to 3rd, hexagonal in profile, widest at centre; remaining joints successively larger to 12th, and more spherical; 13th somewhat less in diameter; 14th ovate, elongate, longer and narrower than preceding joints.

The antennal characters are very variable, especially in the region of joints 3 to 5, and the relative proportions of the segments are of very doubtful value in classification.

Mandibles dark brown, nearly black, curved at tip, the curve following back through practically the whole length; right with a very slightly crenulated biting edge near the base, and a small tooth at the position of the large basal tooth of the left mandible. Left with four even teeth, becoming progressively larger basally, and a large, rounded basal tooth (Fig. 9).

Labrum with sides broadly rounded, longer than broad, and broadest at about the middle; hyaline tip triangular, sharply pointed, projecting as a ridge dorsally, with two hairs at its base (Fig. 10).

Gula as shown in Fig. 12; front margin truncate, lateral angles rather sharply rounded, and the posterior margin rather more narrow than in most species.

Anterior margin of pronotum with a rather deep arcuation involving the median third; no sharp, median emargination; anterior margins round evenly on either side to the antero-lateral angles, at about the anterior third, thence the margins converge

CORRIGENDA.

Page 68, Paragraph 2:—

Omit line 9 and insert instead—

slightly concave dorsally, and rather pointed posteriorly (Fig

rather sharply posteriorly, rounding toward the base; posterior margin feebly arcuate at the middle fourth, the emargination lacking (Fig. 14). An occasional specimen will be found in which, through some accident, the anterior margin of the pronotum has become pressed against the head and raised perpendicularly, to give an outline as shown in Fig. 13. Such cases should be guarded against in making measurements.

MEASUREMENTS AND INDICES.

(Of Soldiers of *Coptotermes oshimai*, sp. nov.).

	Indices	Measurements (in millimeters)		
		Maximum	Minimum	Average
Head				
length with mandibles	—	2·114	2·108	2·114
length	—	1·341	1·278	1·304
length to fontanel	—	1·293	1·229	1·268
maximum breadth	—	1·198	1·118	1·168
minimum breadth	—	0·702	0·687	0·695
index	0·895	—	—	—
contraction index	0·595	—	—	—
Gula				
length	—	0·775	0·734	0·754
maximum breadth	—	0·417	0·383	0·401
minimum breadth	—	0·265	0·243	0·254
average breadth	—	—	—	0·327
index	2·305	—	—	—
contraction index	0·633	—	—	—
maximum breadth index	1·880	—	—	—
minimum breadth index	2·969	—	—	—
Head length divided by				
maximum gular breadth	3·252	—	—	—
minimum gular breadth	5·134	—	—	—
average gular breadth	3·988	—	—	—
gular length	1·729	—	—	-
Fontanel				
length	—	0·109	0·096	0·100
breadth	—	0·168	0·153	0·163
angle of inclination	27°–34°	—	—	—
aperture index	0·613	—	—	—
Labrum				
length	—	0·332	0·286	0·304
length with hyaline tip	—	0·364	0·319	0·344
maximum breadth	—	0·275	0·260	0·265
Pronotum				
maximum length	—	0·446	0·431	0·437
minimum length	—	0·393	0·364	0·384
maximum breadth	—	0·856	0·814	0·834
index	2·031	—	—	—
Length of hind tibia	—	0·960	0·926	0·943
Length of left mandible	—	0·880	0·834	0·858
Total length of insect	—	6·40	6·10	6·25
Length of antenna	—	1·421	1·246	1·325

Described from four soldiers collected by Mr. Ryozo Kanehira at Maros, Celebes, and given to the senior author by Dr. Masu-

mitsu Oshima. The species has been named for Dr. Oshima, who has contributed several papers on termites of the Malayan and Papuan regions.

If measurements are a criterion, *C. oshimai* is closely related to *C. ceylonicus* Holmgren, and *C. heimi* Wassmann. They are medium sized species, superficially much alike. The following table of the more important measurements and indices may serve to help distinguish between them. Those for *C. ceylonicus* and *C. heimi* are from the recent paper of the senior author (Light, 1927).

	C. oshimai	*C. ceylonicus* Holmgren	*C. heimi* Wassmann
Head length	1·304	1·41	1·32
„ breadth	1·168	1·14	1·14
„ index	0·895	0·798	0·866
„ contraction index	0·595	0·643	0·560
Gular index	2·305	2·25	2·56
„ contraction index	0·633	0·618	0·636
„ max. breadth „	1·880	1·82	2·09
„ min. „ „	2·969	2·95	3·29
Pronotal length (min.)	0·384	0·418	0·407
„ „ (max.)	0·437	0·442	0·464
„ breadth	0·834	0·828	0·818
„ index	2·031	1·925	1·878
Fontanel length	0·100	0·104	0·128
„ breadth	0·163	0·143	0·164
„ aperture index	0·613	0·733	0·781
Angle of inclination	27°–34°	15°–23°	30°

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END OF VOLUME XLII., PART I.

[PUBLISHED 31ST OCTOBER, 1929.]

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II., 1930.]

ART. IX.—*On the Relationship between "Pecten" asperrimus Lamarck and "Pecten" antiaustralis Tate, with a description of an Allied Fossil Form.*

By J. H. GATLIFF and F. A. SINGLETON.

(With Plates II.-IV.)

[Read 8th August, 1929; issued separately 7th March, 1930.]

Introduction.

The specific distinctness or otherwise of *Chlamys antiaustralis* (Tate) and *C. asperrimus* (Lamarck) has been the subject of varying opinions. It therefore appeared desirable to examine, in conjunction with series of the Recent shells, the type of the fossil species and as many as possible of the fossil occurrences, one of which we consider to be a hitherto undescribed form.

Genus **Chlamys** (Bolten) Röding, 1798.

CHLAMYS ASPERRIMUS ANTIAUSTRALIS (Tate, 1886).

(Pl. II., Fig. 3; Pl. III., Figs. 6, 7; Pl. IV., Fig. 10*a,b*.)

Pecten asperrimus Lamarck, var. Tate, 1882, p. 34.
Pecten antiaustralis Tate, 1886, pp. 106-7, pl. ix., f. 7*a-c*.
Harris, 1897, pp. 315-6. Tate, 1899, p. 269.

Historical Account.—Tate in 1886 gave specific rank to fossil shells from the upper beds (Upper Aldingan=Kalimnan) at Aldinga, South Australia, which he had previously recorded as *Pecten asperrimus*, var. He admitted the very close alliance with the Recent shells listed by him as *P. australis* Sowerby, and thought by him to be probably identical with *P. asperrimus* Lamarck, an identification now generally accepted. He cited as distinctive characters "the *lamelliform* ornamentation of the convex ribs and riblets, whilst in *P. australis* they are angular, and beset with distant scaly serratures or spinous scales; moreover, the valves, especially the left valve, is more convex". He further stated (1886, p. 107), "The young of the two species are much alike, having simple ribs, developing with age a riblet on each side. Rarely does *P. australis* acquire more, but *P. antiaustralis* does so as a rule, and aged examples exhibit two or three on each flank, and often one in the furrow, whilst the concentric lamellæ are continuous across the furrows. The ears of the fossil species are larger, and the shell attains to greater dimensions. *P. antiaustralis*, however, exhibits variations in the degree of convexity of the valves and ribs, whilst *P. australis*—the commonest shell on the South Australian coast—is true to its type."

Observations on the Holotype.—The type of *Pecten anti-australis* Tate, from the University of Adelaide, has been compared by us with a series of fossil topotypes as well as with a long series of Recent *Chlamys asperrimus* (Lamarck) dredged in Westernport, Victoria (J. H. G. Coll.).

While some fossil examples (Pl. II., Fig. 4) appear to us to be inseparable from the Recent *Chlamys asperrimus, s. str.*, they intergrade with the fossil holotype (Pl. II., Fig. 3; Pl. III., Fig. 6), which seems to be an extreme form. Of the distinctive characters relied upon by Tate, and above quoted, we are unable to perceive any difference in convexity of the valves, number of lateral riblets, or size of the ears. We admit the greater width of the ribs (Pl. IV., Figs. 10*a,b*) as compared with most Recent examples (Pl. IV., Figs. 11*a,b*), though some of them approach it somewhat in this regard, and the apparently more angular character of the ribs of the latter is due solely to their narrowness. Actually they are equally rounded. Owing to the wider ribs of the fossil holotype the ornament in the adult stage is lamelliform (Pl. IV., Fig. 10*b*), but in the juvenile stages the scales where preserved are more pointed, owing to the narrower base from which they spring. Correspondingly in Recent shells there is a tendency for the spinous scales to become more lamelliform towards the ventral margin. Their spacing varies during growth of the shell, but is in general more close in the fossil holotype.

The lateral riblets in Recent shells are at least as numerous as in Tate's type specimen, and his observations in this regard were apparently due to comparison with relatively young examples of the Recent species, which, as seen in the illustrations, attains at least an equal size in the gerontic stage.

Apart from the lamelliform character of the mature ornament, the chief distinctive feature of the fossil holotype, although not mentioned by Tate, lies in the finer and more numerous radial ribs of the anterior ear of the right valve, which, like the corresponding ear of the left valve, is imperfect. That this feature is a variable one is indicated by our figures of a fossil topotype with coarse ribbing of this ear (Pl. III., Fig. 7), and of a Recent shell with relatively fine auricular ribs (Pl. II., Fig. 2.).

Dimensions of Holotype.—Width (ant.-post.), 68·2 mm. Height (umbono-ventral), 67·9 mm. Thickness of paired valves, 26·3 mm. Tate's dimensions, 58 × 58 × 25 mm., are evidently erroneous, as the specimen is marked as the figured one.

Conclusions.—Although we reject the majority of Tate's criteria for distinction between his species and the living form, we recognise variation from the latter, notably in regard to the lamelliform character of the closely spaced scales on the ribs in the gerontic stage. It is apparent that Tate has selected an extreme form as holotype, and the presence, in a series of fossil topotypes, of forms annectent in characters with a shell (Pl. II., Fig. 4) identified by us with *Chlamys asperrimus, sensu stricto,*

impels us to accord his species only subspecific rank as C. *asperrimus antiaustralis*.

In the case of juvenile and of somewhat worn specimens, it is very difficult to make subspecific distinctions, and a reference to *Chlamys asperrimus, sensu lato*, is often all that is possible.

CHLAMYS ASPERRIMUS ASPERRIMUS (Lamarck, 1819).

(Pl. II., Figs. 1, 2, 4; Pl. III., Fig. 5; Pl. IV., Figs. 11*a,b*, 12.).

Pecten asperrimus Lamarck, 1819, p. 174. Delessert, 1841, pl. xv., f. 1*a,b*. Sowerby, 1842, p. 75, pl. xvii., f. 156-8. Reeve, 1853, pl. xx., f. 75.

Pecten australis Sowerby, 1842, p. 76, pl. xix., f. 210, 220. Reeve, 1853, pl. xxv., f. 103*a,b*.

Chlamys asperrimus (Lamarck). Pritchard and Gatliff, 1904, p. 264.

Observations on the Fossil Plesiotype.—The right valve here figured (Pl. II., Fig. 4; Pl. IV., Fig. 12), from the same locality and horizon as the holotype of *antiaustralis* Tate, appears to us to agree in all essential characters with Recent *asperrimus, s. str.* We have enumerated the points of distinction from *antiaustralis* in dealing with that subspecies, and have indicated the occurrence of intermediate forms.

Dimensions of Fossil Plesiotype.—Width, (ant.-post.) 66·8 mm. Height, 67·1 mm. Thickness of paired valves, 25·2 mm.

Dimensions of Recent Plesiotypes.—Larger: Width, 68·0 mm. Height, 67·3 mm. Thickness of paired valves, 27·1 mm. Smaller: 60·6 × 61·1 × 21·9 mm.

CHLAMYS ASPERRIMUS DENNANTI, subsp. nov.

(Pl. III., Figs. 8, 9; Pl. IV., Fig. 13*a,b*.)

Pecten asperrimus Lamarck: Dennant, 1887, p. 236 (list name). Harris, 1897, p. 314. (*Non P. asperrimus* Lamarck, *s. str.*)

Description of Holotype.—Right valve, suborbicular, slightly oblique, gently convex. Umbonal angle 79°, acute; anterior margin slightly concave, meeting the antero-ventral edge with a distinct angulation; the ventral margin almost circular, passing posteriorly into the concave post-umbonal margin.

Surface somewhat evenly convex, slightly depressed ventrally, bearing 27 prominent radiating ribs with two minor ribs anteriorly. Interspaces nearly filled with minor radial riblets, up to three on either flank of each main rib, between which centre of interspace is concave and transversely ornamented by close, irregularly spaced growth lines; about 15 riblets posterior to the last main rib. In places the interspaces show the very fine radial ornament seen in fossil and recent examples of *asperrimus, sensu lato*. Major ribs prominent, evenly convex, bearing numerous trans-

verse lamellate scales, irregularly spaced, about 9-10 in 5 mm., convex towards umbo. Interstitial riblets ornamented with closely set spinose scales, about 14-17 in 5 mm. Ears prominent, unequal, bearing numerous radial ribs carrying closely spaced erect scales. Anterior ear descending from dorsal margin in a curve to the prominent byssal sinus, bearing 9 prominent ribs with an intercalated riblet between each of the lower pairs towards their margins; ctenolium present. Left ear obliquely truncated posteriorly, with about 21 radii alternating in size, less prominent than on right ear.

Dimensions of Holotype.—Width (ant.-post.), 53·2 mm. Height, 58·8 mm. Thickness of valve, 11 mm.

Description of Paratype (Pl. III., Fig. 9).—Left valve slightly smaller than holotype (not a counterpart), of similar outline, but somewhat narrower and slightly more convex. Radial ribs 23, with similar ornament and interstitial riblets.

Dimensions of Paratype.—48·5 × 57·0 × 11 mm.

Observations.—The present subspecies differs from *asperrimus, s. str.,* and *antiaustralis* in the greater narrowness of the shell, the outline of which resembles *Chlamys funebris* (Reeve) of the West Australian coast. The latter is, however, slightly more orbicular than *dennanti* and the ribs are broader and heavier, and lack the numerous interstitial riblets of the fossil form. The principal ribs in *dennanti* are rather narrower than in *asperrimus, s. str.,* and are relatively more prominent.

Fossil Records of Pecten asperrimus.

In addition to Tate's original usage of *asperrimus* var. for the Kalimnan fossils later called *antiaustralis,* the above name was used by Dennant (1887, p. 236) and Harris (1897, p. 314) for Werrikooian fossils herein named *dennanti,* n. subsp. We have, however, restored *asperrimus,* s. str., to the Kalimnan record as an associate of the subspecies *antiaustralis.*

Tenison Woods (1879, p. 56) states of *Pecten asperrimus,* "Fossil specimens are very common in the pliocene rocks of Government House quarry, Adelaide," which refers probably to the Kalimnan horizon, but whether the name is used in the restricted sense of the present paper is unknown to us.

Recent Records of Pecten antiaustralis.

Hedley (1911, p. 96) has erroneously recorded as *Chlamys antiaustralis* shells from 100 fathoms off Cape Pillar, Tasmania, which have since been described as *Chlamys instar* by Iredale (1925, p. 251, pl. xli., figs. 5-7), while other specimens recorded by Hedley (loc. cit.) from a similar depth off Wollongong, N.S.W., were referred by Iredale to a second new species, *Chlamys famigerator* (1925, p. 252, pl. xli., figs. 1, 2), to which

he suggests perhaps may belong Hedley's deepwater shells from off Cape Wiles, South Australia.

We are not aware of any Recent shells which are referable to *antiaustralis,* s. str.

Summary.

1. The fossil pelecypod *Pecten antiaustralis* Tate, described from the Upper Beds (Kalimnan=Lower Pliocene?) at Aldinga, South Australia, is considered to be a subspecies of the Recent *Pecten asperrimus* Lamarck, and should bear the name *Chlamys asperrimus antiaustralis* (Tate). It is accompanied at the type locality and horizon by shells identified by us as *Chlamys asperrimus* (Lamarck), *s. str.*

2. The shells recorded as *Pecten asperrimus* from the Werrikooian (Upper Pliocene or Pleistocene?) beds of the Glenelg River, Western Victoria, are described as *Chlamys asperrimus dennanti,* subsp. nov.

3. The subspecies *antiaustralis* differs from *asperrimus,* s. str., chiefly in the wider ribs and lamelliform character of the mature ornament. In *dennanti* the ribs are even narrower and more prominent than in the latter, while the shell is narrower than in the other two subspecies.

Acknowledgments.

We are under obligations to Acting Professor Madigan, of the University of Adelaide, for affording us the opportunity of examining the fossil type from the Tate Museum of the Department of Geology; to Mr. W. J. Kimber, of Adelaide, for the loan of his series of topotypes from the Upper Beds at Aldinga; and to the Director, Mr. J. A. Kershaw, and the Palaeontologist of the National Museum, Melbourne, Mr. F. Chapman, for allowing us to describe a new subspecies from material in the Dennant collection in that institution. Our thanks are also due to Messrs. F. A. Cudmore and A. C. Collins for the loan of Victorian fossil material, and to Miss J. Wilson-Smith for the photographs.

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Explanation of Plates.

The figures in Plates II. and III. are approximately natural size; those in Plate IV. are enlarged about 2½ times linear.

PLATE II.

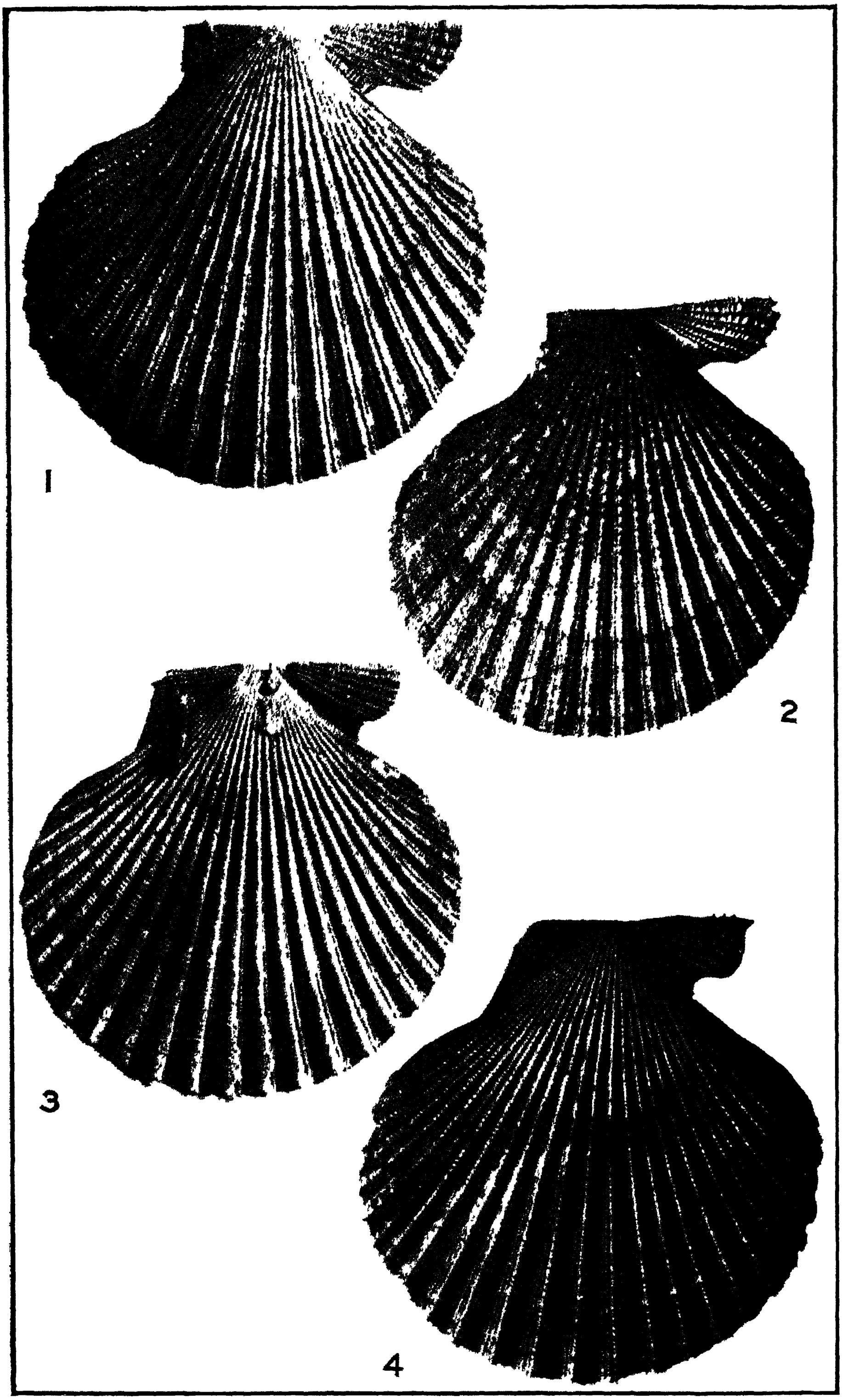
Figs. 1, 2.—*Chlamys asperrimus asperrimus* (Lamarck). Recent. Westernport, Vic. Plesiotypes, right valves, showing coarse and fine ribbing of anterior ear respectively. Ex Gatliff Coll.; pres. to Melbourne University Geol. Dept., Reg. Nos. 989 and 991.

Fig. 3.—*C. asperrimus antiaustralis* (Tate). Tertiary (Kalimnan). Aldinga, S.A., upper beds. Holotype of *Pecten antiaustralis* Tate, right valve. Tate Coll., Adelaide University Geol. Dept.

Fig. 4.—*C. asperrimus asperrimus* (Lamarck). Tertiary (Kalimnan). Aldinga, S.A., upper beds. Plesiotype, right valve. Kimber Coll.

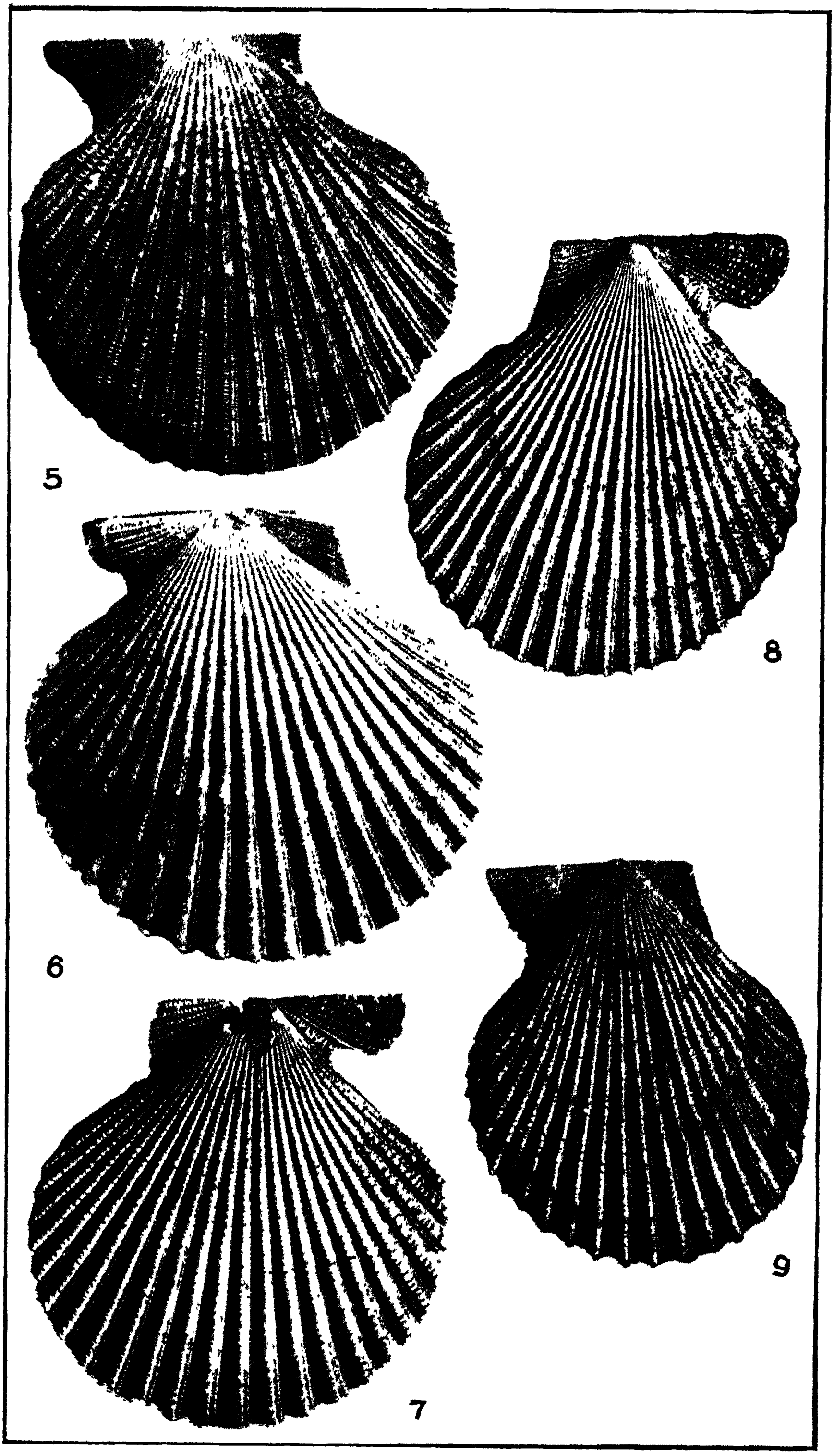
PLATE III.

Fig. 5.—*Chlamys asperrimus asperrimus* (Lamarck). Recent. Plesiotype, left valve, counterpart of Fig. 1. Ex Gatliff Coll.; pres. to Melb. Univ. Geol. Dept., Reg. No. 990.



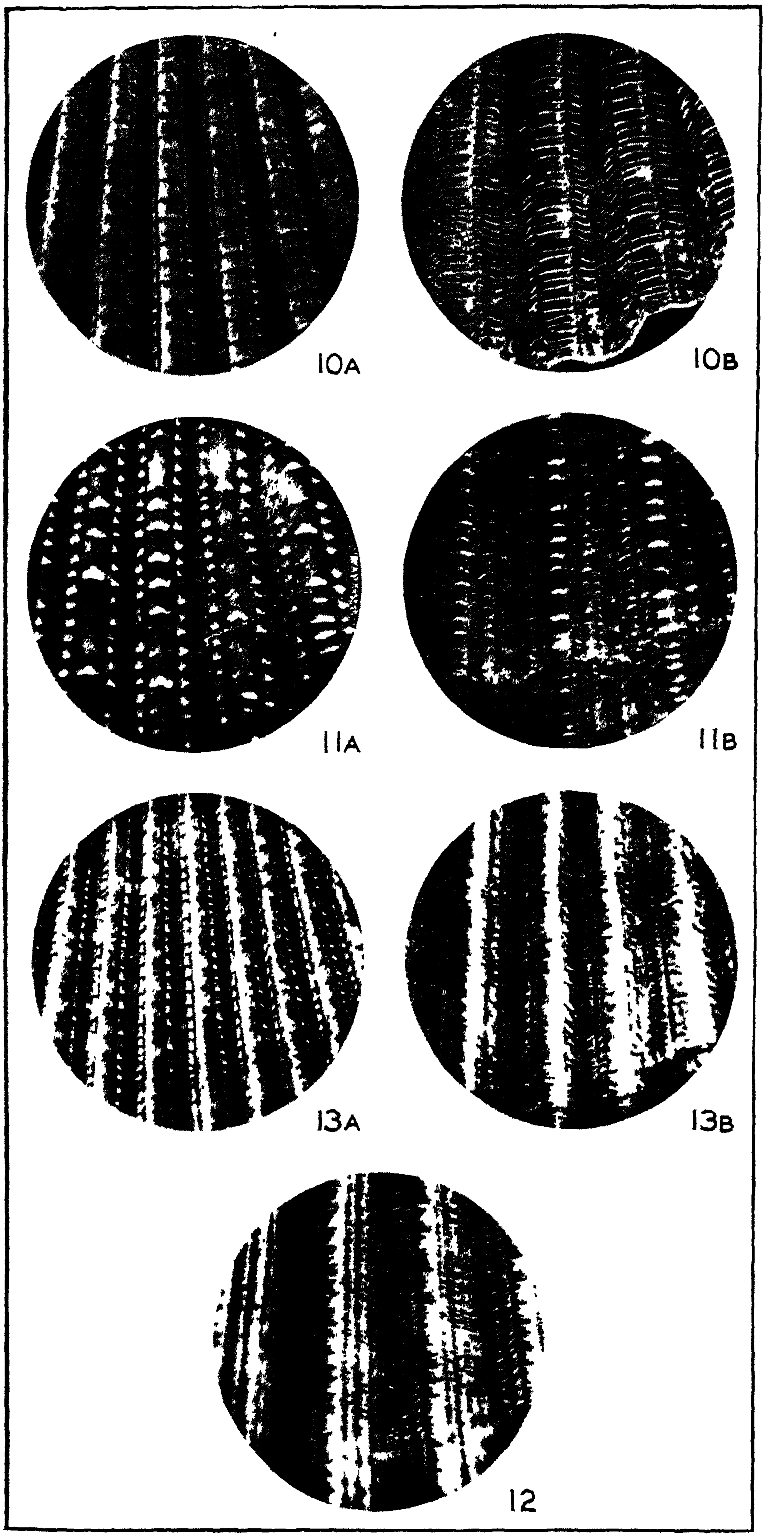
J Wilson-Smith photo

Chlamys asperrimus. Recent and Fossil.



J. Wilson-Smith photo.

Chlamys asperrimus. Recent and Fossil.



J. Wilson-Smith photo.

Ornament of Chlamys asperrimus.

Fig. 6.—*C. asperrimus antiaustralis* (Tate). Tertiary (Kalimnan). Holotype, left valve, counterpart of Fig. 3.

Fig. 7.—*C. asperrimus antiaustralis* (Tate). Tertiary (Kalimnan). Aldinga, S.A., upper beds. Plesiotype, right valve, showing coarser auricular ribbing than in holotype. Kimber Coll.

Fig. 8.—*C. asperrimus dennanti,*, subsp. nov. Tertiary (Werrikooian). Glenelg River above Limestone Creek, Vic. Holotype, right valve. Dennant Coll., Nat. Mus., Melb., Reg. No. 13503.

Fig. 9.—*C. asperrimus dennanti*, subsp. nov. Same locality and horizon. Paratype, left valve (not a counterpart of Fig. 8). Dennant Coll., Nat. Mus., Reg. No. 13504.

PLATE IV.

Fig. 10.—*C. asperrimus antiaustralis* (Tate). Tertiary (Kalimnan). Enlarged ornament of holotype (Fig. 3). (*a*) near centre; (*b*) near antero-ventral margin.

Fig. 11.—*C. asperrimus asperrimus* (Lamarck). Recent. Enlarged ornament of plesiotype (Fig. 1). (*a*) near centre; (*b*) near antero-ventral margin.

Fig. 12.—*C. asperrimus asperrimus* (Tate). Tertiary (Kalimnan). Enlarged ornament of plesiotype (Fig. 4), near antero-ventral margin.

Fig. 13.—*C. asperrimus dennanti*, subsp. nov. Tertiary (Werrikooian). Enlarged ornament of holotype (Fig. 8). (*a*) near centre; (*b*) near antero-ventral margin.

[Proc. Roy. Soc. Victoria, 42 (N.S.), Pt. II., 1930.]

Art. X.—*Contributions to the Flora of Australia, No. 36.**

By ALFRED J. EWART, D.Sc., Ph.D., F.R.S., F.L.S.

(With Plate V.)

[Read 14th November, 1929; issued separately 7th March, 1930.]

The first part of this paper gives further data in regard to *Eucalyptus Gilleni* Ewart and Kerr, a species collected in 1924 on Mt. Gillen in Central Australia when in fruit. As attempts to obtain the flower failed it was described in 1926 (*Proc. Roy. Soc. Vic.*, n.s., xxxix. (1), Contributions No. 32) from leaf and fruit, and as the latter contained fertile seed these were germinated and planted in the System Garden at the University. The plant grew into rather a handsome shrub 6 feet high, but did not flower until Autumn, 1929, developing ovate green buds with a conical inner and outer operculum, and pale fertile stamens, with small nearly globular anthers, with a gland on the back and opening by nearly parallel slits. The stamens were somewhat similar to those of *E. parvifolia* Cambage (Maiden, *Syst. Rev.*, iii., Pl. 104), but in all other respects the two plants differ widely. It shows some affinity to *E. cosmophylla* F.v.M., a South Australian species, in habit and general characters, but its domed fruit with projecting valves is quite dissimilar, and neither the inner nor outer operculum of *E. Gilleni* is acuminate, but rather bluntly conical. Nevertheless it may be related to *E. cosmophylla*.

The remainder of the paper consists of a preliminary list of plants collected in North West Australia during 1927, when visiting the Kimberley district to investigate the Walk-About Disease of Horses. It gives the localities and times of flowering of the plants collected. The collection was made in duplicate, one set being retained at Perth. All plants not identified in the field were examined and named by Mr. Gardner, Government Botanist at Perth, and the identifications checked later by comparison of the specimens with types in the Melbourne Herbarium.

List of Plants from the Kimberleys, North West Australia.

By

A. J. EWART and C. A. GARDNER.

ACANTHACEAE.

Dicliptera glabra Dcne.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
Justicia procumbens Linn.	Fitzroy Rd., 18 m. from Yeeda, N.W.A., Apr., 1927.

*No. 35 in *Proc. Roy. Soc. Vic.*, n.s., xli. (1), 1928, p. 59.

AIZOACEAE (FICOIDEAE).

Trianthema oxycalyptra F.v.M.	6 m. E. of Derby, N.W.A., Apr., 1927. Gogo stn., Fitzroy R., N.W.A., May, 1927.
T. pilosa F.v.M.	6 m. E. of Derby, N.W.A., Apr., 1927.

AMARANTHACEAE.

Ptilotus corymbosus R. Br.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
Gomphrena brachystylis F.v.M.	Derby, N.W.A., Apr., 1927.
G. flaccida R. Br.	6 m. E. of Derby, N.W.A., Apr., 1927.
G. leptoclada Benth.	Grant range, Liparinga, N.W.A., April, 1927.
G. tenella Benth.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.
Amaranthus pallidiflorus F.v.M.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Trichinium exaltatum Benth.	Gogo stn., Fitzroy R., N.W.A., May, 1927.

BORAGINACEAE.

Heliotropium paniculatum R.Br.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
H. tenuifolium R. Br.	6 m. E. of Derby, N.WA.., Apr., 1927.

CAPPARIDACEAE.

Cleome tetrandra Banks.	10 m. E. of Derby, Apr., 1927.
C. viscosa Linn. (*Polanisia viscosa*)	Derby, N.W.A., Apr., 1927.

CARYOPHYLLACEAE.

Polycarpaea corymbosa Lam.	Derby, N.W.A., Apr., 1927.
P. longiflora F.v.M.	Derby, N.W.A., Apr., 1927.

COMBRETACEAE.

Terminalia Thozetii Benth.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
T. volucris, R. Br.	6 m. E. of Derby, N.W.A., Apr., 1927.

COMMELINACEAE.

Commelina lanceolata R. Br.	Between Liparinga and Noonkanbah, Apr., 1927.

CONVOLVULACEAE.

Ipomoea angustifolia Jacq.	Derby, N.W.A., Apr., 1927.
I. heterophylla R. Br. (seeds not glabrous)	Derby, N.W.A., Apr., 1927.
I. dissecta Willd.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
I. eriocarpa R. Br.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Evolvulus alsinoides Linn.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Cressa cretica Linn.	Derby, N.W.A., Apr., 1927.

CUCURBITACEAE.

Cucumis trigonus Roxb.	Fitzroy Rd., 12 m. from Yeeda, and near Oscar Range, Rd. to Leopold, N.W.A., Apr., 1927.

CYPERACEAE.

Fimbristylis solidifolia F.v.M.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.

DROSERACEAE.

Byblis liniflora Salisb.	Shore Rd. to Leopold, Derby, N.W.A., Apr., 1927.
Drosera indica Linn.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.

EUPHORBIACEAE.

Euphorbia chrysochaeta W.V.F.	Derby, N.W.A., Apr., 1927.
Sebastiania chamelaea F.v.M.	Yeeda, 28 m. S.E. of Derby, N.W.A., Apr., 1927.
Phyllanthus maderaspatanus Linn.	4 m. N.E. of Derby, N.W.A., Apr., 1927.

GOODENIACEAE.

Goodenia lamprosperma F.v.M.	Liparinga, Fitzroy R., N.W.A., Apr., 1927.
G. sepalosa F.v.M.	6 m. E. of Derby, Apr., 1927.
Velleia panduriformis A. Cunn.	Yeeda, 28 m. S.E. of Derby, N.W.A., Apr., 1927.

GRAMINEAE.

Eriachne ovata Nees.	Derby, N.W.A., Apr., 1927.
Eragrostis tenella Beauv.	3 m. S. of Gogo stn., Fitzroy, N.W.A., Apr., 1927.

Ischaemum laxum R. Br.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Andropogon australis Spreng.	Derby, N.W.A., Apr., 1927.
A. bombycinus R. Br.	Between Liparinga and Noonkanbah, N.W.A., Apr., 1927.
Leptochloa polystachya Benth.	3 m. S. of Gogo stn., Fitzroy R., N.W.A., May, 1927.
Pennisetum cenchroides Rich.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Chionachne cyathopoda F.v.M.	Fitzroy crossing, N.W.A., May, 1927.
Pappophorum nigricans R. Br.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Panicum airoides R. Br.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
P. colonum Link. (*Echinochloa*)	3 m. S. of Gogo stn., Fitzroy R., N.W.A., May, 1927.
P. distachyum Linn. (*Brachiaria*)	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Themeda membranacea Lindl. (*Anthistiria*)	Gogo stn., Fitzroy R., N.W.A., May, 1927.

LEGUMINOSAE.

Sesbania aculeata Pers.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.
Indigofera enneaphylla Linn.	Derby, N.W.A., Apr., 1927.
I. hirsuta Linn.	Derby, N.W.A., Apr., 1927.
I. linophylla Retz.	Derby, N.W.A., Apr., 1927.
I. viscosa Lam.	Derby, N.W.A., Apr., 1927.
Æschynomene indica Linn.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927; also Liparinga, Fitzroy Rd.
Zornia diphylla Pers.	6 m. E. of Derby, N.W.A., Apr., 1927.
Neptunia monosperma F.v.M.	Liparinga, N.W.A., Apr., 1927.
Vigna lanceolata Benth.	Liparinga, Fitzroy R., Billabong Flat, N.W.A., Apr., 1927.
Crotalaria crispata F.v.M.	Mt. Anderson, Fitzroy Rd., N.W.A., Apr., 1927.
C. trifoliastrum Willd.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
Glycine tomentosa Benth.	4 m. N.E. of Derby, N.W.A., Apr., 1927.

LOGANIACEAE.

Mitrasacme exserta F.v.M.	6 m. E. of Derby, N.W.A., Apr., 1927; also Fitzroy R., 28 m. from Yeeda, Apr., 1927.
M. prolifera R. Br.	6 m. E. of Derby, N.W.A., Apr., 1927.

LORANTHACEAE.

Loranthus Exocarpi Behr.	On *Hakea*, 6 m. E. of Derby, N.W.A., Apr., 1927.

LYTHRACEAE.

Ammannia multiflora Roxb.	3 m. S. of Gogo stn., Fitzroy R., May, 1927.

MALVACEAE.

Cienfuegosia latifolia Benth.	4 m. N.E. of Derby, Apr., 1927.
Abutilon Andrewsianum W.V.F.	10 m. E. of Derby, N.W.A., Apr., 1927.
A. Cunninghamii Benth.	Derby, N.W.A., Apr., 1927.
Sida virgata Hook.	Derby, N.W.A., Apr., 1927.
Hibiscus cannabinus Linn.	Fitzroy Rd., 12 m. from Yeeda, N.W.A., Apr., 1927.
H. panduraeformis Burm.	8 m. from Yeeda on Fitzroy R., N.W.A., Apr., 1927.

MYRTACEAE.

Eucalyptus perfoliata R. Br.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
E. terminalis F.v.M.	Shore Rd. to Leopold. 10 m. from Derby, N.W.A., Apr., 1927.
Melaleuca alsophila A. Cunn.	Shore Rd. to Leopold. 10 m. from Derby, N.W.A., April, 1927.
M. Leucadendron Linn. var. *coriacea*	Rd. to Leopold, Derby, N.W.A., and between Jubilee stn. and Fitzroy Crossing, Apr., 1927.
M. Leucadendron, Linn. var. *Crosslandiana*	Between Jubilee stn. and Fitzroy Crossing, N.W.A., Apr., 1927.

NYCTAGINACEAE.

Boerhaavia diffusa Linn.	6 m. E. of Derby, N.W.A., Apr., 1927.

ONAGRACEAE.

Ludwigia parviflora Roxb.	3 m. S. of Gogo stn., Fitzroy R., N.W.A., May, 1927.

POLYGALACEAE.

Polygala chinensis Linn. (*P. Tepperi* F.v.M.)	Yeeda, 28 m. S.E. of Derby, N.W.A., Apr., 1927.

PORTULACACEAE.

Calandrinia strophiolata F.v.M.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.
Portulaca tuberosa Roxb.	Shore Rd. to Leopold, 10 m. from Derby. N.W.A., Apr., 1927.

PROTEACEAE.

Grevillea agrifolia A. Cunn.	Yeeda, 28 m. S.E. of Derby, N.W.A., Apr., 1927.

RUBIACEAE.

Oldenlandia scleranthoides Benth. and Hook.	Shore Rd. to Leopold, Derby, N.W.A., Apr., 1927.
Spermacoce auriculata F.v.M.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.

SANTALACEAE.

Santalum lanceolatum R. Br.	Jubilee stn., 26 m. W. of Fitzroy Crossing. N.W.A., Apr., 1927.

SAPINDACEAE.

Distichostemon phyllopterus F.v.M.	4 m. N.E. of Derby, N.W.A., Apr., 1927.

SCROPHULARIACEAE.

Morgania glabra R. Br.	Between Noonkanbah and Liparinga, N.W.A., Apr., 1927.
M. parviflora Benth.	4 m. N.E. of Derby, N.W.A., Apr., 1927.
Buchnera urticifolia R. Br.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.
Mimulus gracilis R. Br.	Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.
Striga multiflora Benth.	Gogo stn., Fitzroy R., N.W.A., May, 1927.
Limnophila hirsuta Benth.	Mt. Anderson, Fitzroy Rd., N.W.A., Apr., 1927.

TILIACEAE.

Triumfetta plumigera F.v.M. 4 m. N.E. of Derby, N.W.A., Apr., 1927.

STERCULIACEAE.

Waltheria indica Linn. Shore Rd. to Leopold from Derby, N.W.A., Apr., 1927.

STYLIDIACEAE.

Stylidium leptorhizum F.v.M. var. *pilosum* Benth. 6 m. E. of Derby, N.W.A., Apr., 1927.

VIOLACEAE.

Hybanthus aurantiacus F.v.M. Gogo stn., Fitzroy R., N.W.A., May, 1927.

H. enneaspermus F.v.M. Gogo stn., Fitzroy R., N.W.A., May, 1927.

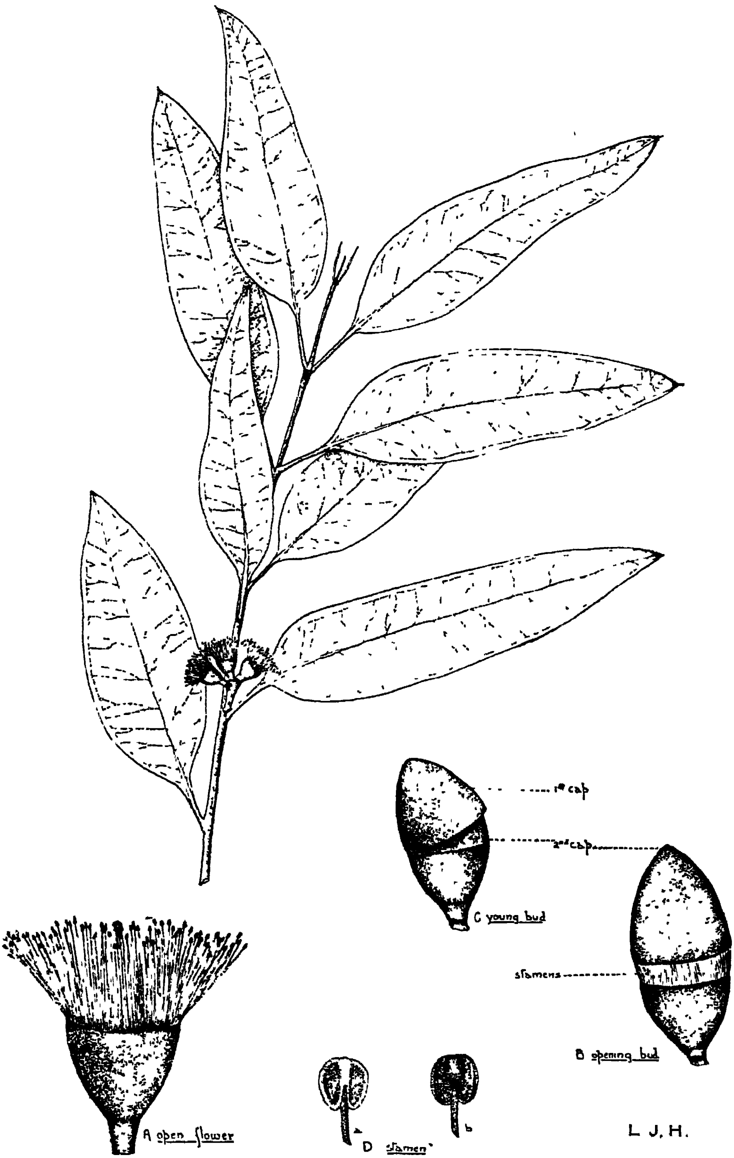
XYRIDACEAE.

Xyris complanata R.Br. Shore Rd. to Leopold, 10 m. from Derby, N.W.A., Apr., 1927.

Explanation of Plate V.

Eucalyptus Gilleni Ewart and Kerr, 1926.

From plant grown in System Garden, University of Melbourne, from seed collected in 1924, on Mt. Gillen, Central Australia.



EUCALYPTUS GILLENI

[PROC. ROY. SOC. VICTORIA, 42 (N S.), PT. II., 1930.]

ART. XI.—*A Correlation between Leaf Dimensions and Osmotic Concentrations in Chickweeds.*

By GWENDOLYN M. CHENEY, B.Sc.
(Botanical Department, University of Melbourne).

(Communicated by Dr. R. T. Patton.)

[Read 14th November, 1929; issued separately 7th March. 1930.]

Introduction.

For many years the succulence exhibited by a large number of coastal and salt marsh plants has been recognised as being due either directly or indirectly to the effect of the sodium chloride and other salts present in the soil. While several experiments have been made to show the effect of varying concentrations of NaCl on such succulent halophytes themselves, few attempts have been made to reproduce the same effect in normal mesophytic plants by adding salt to the medium in which they grow. One of the earliest experiments of this nature was carried out by Batalin (1) in 1876. He found that " salt plants " lose their normal characteristics when grown in non-saline soils, and also that the leaves of *Salicornia herbacea* became succulent if watered with NaCl solutions. Lesage (2), working with *Lepidium sativum,* showed that if a solution of salt was added to the soil the leaves became thicker, the palisade tissue was greatly increased, and there was a reduction in the amount of chlorophyll present. Lesage also stated that with increasing concentration of salt the thickness of the leaf was increased, accompanied by a decrease in the height of the plant and a reduction of leaf surface. Conversely, he stated that with a decrease in salt concentration the thickness of the leaf decreased, accompanied by an increase in height and leaf surface. These latter statements of Lesage, however, are found to be at variance, to a certain extent, with the results obtained in the present investigation into the correlation between salt concentration in the soil and the leaf dimensions of *Stellaria media* and *Cerastium vulgatum*. Rudolfs (6), in 1927, also found that the addition of salt to the soil increased the height of asparagus plants, which is contradictory to Lesage's statement. There is, however, in such cases, always a possibility that the addition of salt may have the effect of increasing the absorption of nutrient food materials from the soil which otherwise would be available in less amount. Further work done on the effect of salt on plants has been concerned mainly with the effect on height, growth, and other features, or with the effect on halophytes themselves.

Methods of Experiment.

Healthy young seedlings of *Stellaria media* and *Cerastium vulgatum* were selected, at approximately the same stages of growth. Five pots of garden soil were set out for *Stellaria,* and five for *Cerastium,* and in each were planted four seedlings. These were watered with the following solutions of sodium chloride: 1 gm./2000 ccs., 1 gm./1000 ccs., 1 gm./500 ccs., and 1 gm./100 ccs. Tap water was used as a control in the fifth pot of the series. Watering of the seedlings was carried out by means of sprinkler-topped bottles containing the solutions. In watering care was taken to add the solution of NaCl until it emerged from the bottom of the pots, so that there should not be any cumulative increase in concentration in the pots as the result of evaporation. The seedlings were watered with salt solution every three days, and if necessary with tap water on the intervening days.

After four weeks the effect of the different solutions of salt on the plants was very marked, a gradation being shown from the control pot up to those to which 1/100 salt had been added. The concentration of 1/100 NaCl proved to be too great for tolerance by the *Cerastium* plants, and at the end of three weeks they began to wilt, finally dying at the end of about four weeks.

As the amount of added salt was increased, the leaves of the plants of both *Stellaria* and *Cerastium* became longer, broader, and slightly thicker, and also appeared more succulent. They became lighter green in colour, and had a more translucent appearance.

In observing the *Stellaria* plants, though the leaves of those watered with 1/2000 NaCl were seen to be slightly larger than those of the control, the first marked increase in succulence was shown by the plants watered with 1/1000 NaCl. They were quite healthy and flowering profusely, but were lighter green in colour than the control. The plants watered with 1/500 NaCl were unfortunately at an earlier stage of growth than those in the other pots, and though showing the same marked features produced by the increase in salt concentration, the dimensions of their leaves could not be measured. A most remarkable contrast was shown when the plants watered with 1/100 NaCl were compared with the control plants. They appeared very succulent, the leaves being so pale in colour as to be hardly green, with a waxy bloom on the epidermis. The stems were thick and succulent, and very light green in colour. The leaves were extremely large and thick, with the petioles bent backwards in a peculiar fashion. The single row of hairs on the stems was apparently unaffected. A further marked difference from the control was the shortness of the internodes. At the end of six weeks, though still flowering quite well, the stems began to wilt at the base.

In order to demonstrate numerically a correlation between the dimensions of the leaves and the concentration of the added salt, ten adult leaves were taken from each pot and measured for

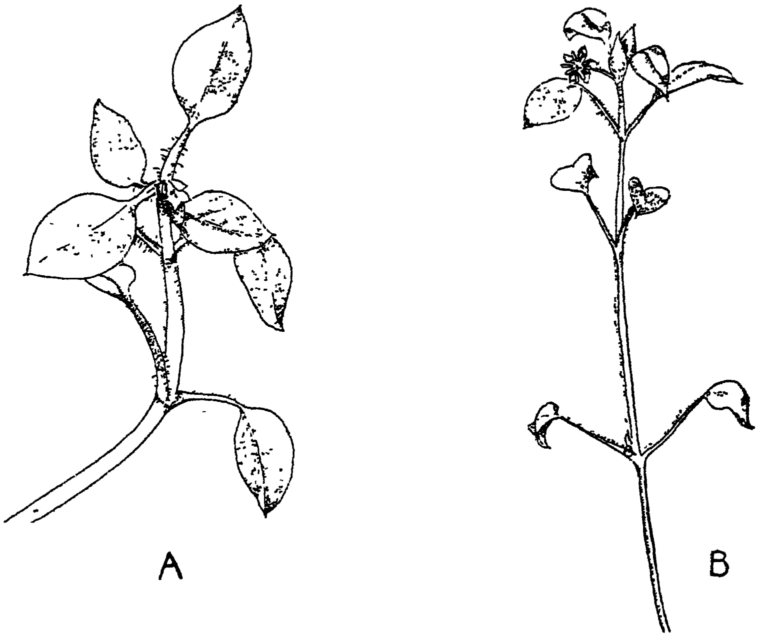


FIG. 1—Stem and leaves of *Stellaria media*.

A. From a plant watered with 1:1000 NaCl.
B. From a control plant.

length, breadth and thickness. Length and breadth were measured with calipers, the greatest width being taken, and thickness was measured with a Leitz micrometer gauge. The mean values of these dimensions, when plotted against the salt concentrations, show a uniformly rising curve from the control to the 1/100 concentration. An analysis of the tap water used for the control showed only 13 parts per million to be present. Owing to the smallness of this amount the values for the leaf dimensions of the control could not be plotted.

TABLE I.—Mean values of length, breadth, and thickness of *Stellaria* leaves in various concentrations of NaCl.

	Control. cms.	1/2000 NaCl. cms.	1/1000 NaCl. cms.	1/100 NaCl. cms.
Length	1·006	1·325	1·352	1·458
Breadth	0·693	0·735	0·875	0·925
Thickness . . .	0·0322	0·0349	0·0391	0·0454

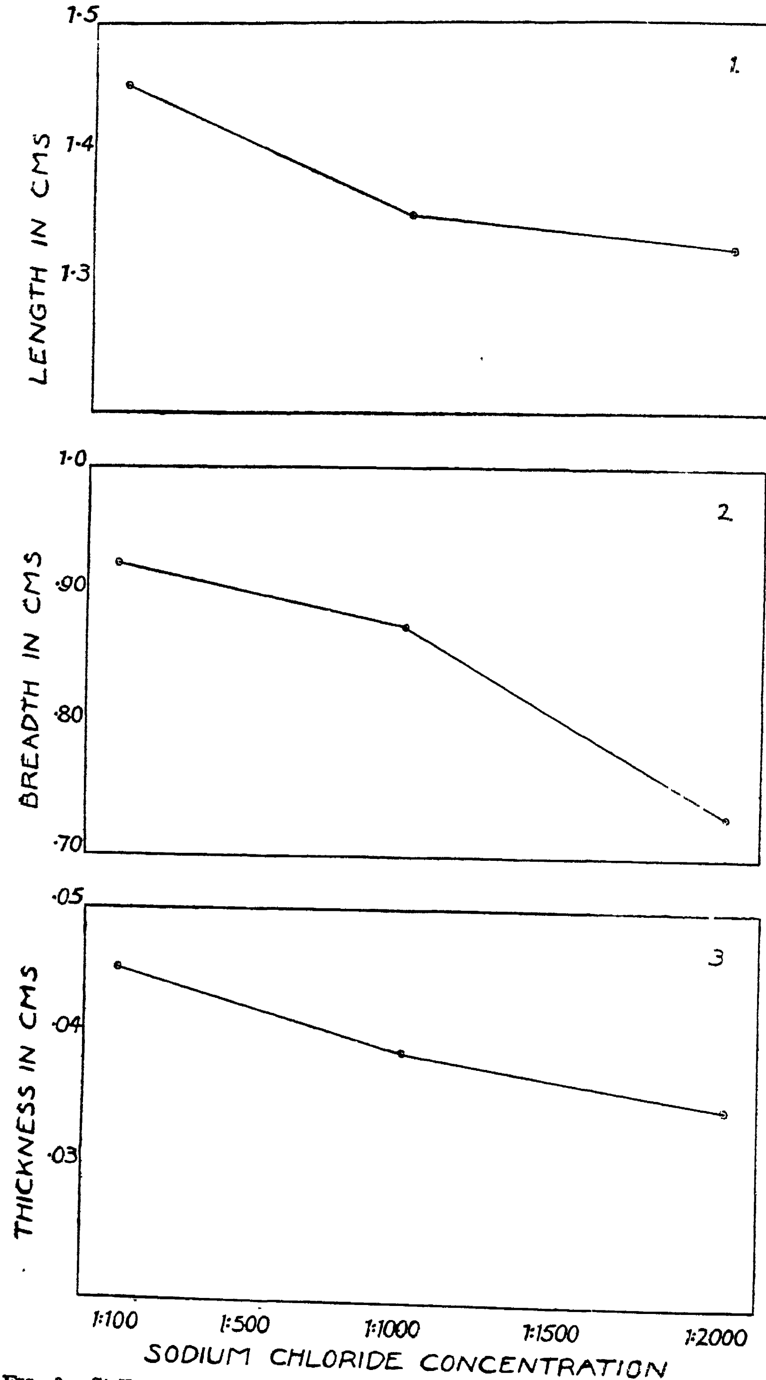


FIG. 2.—*Stellaria media*. Graphs showing increase in (1) length, (2) breadth, and (3) thickness of *Stellaria* leaves with increase in concentration of NaCl.

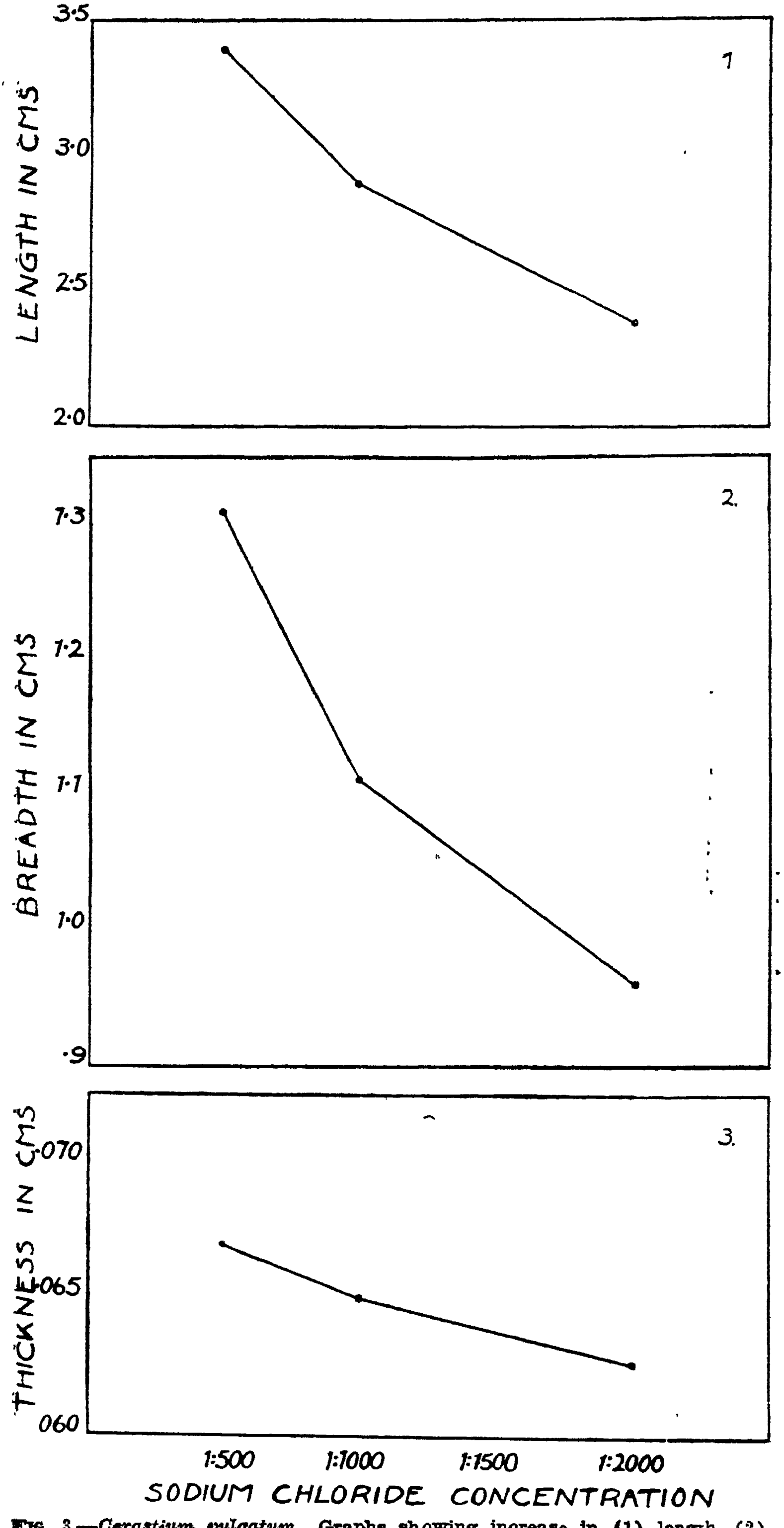


FIG. 3.—*Cerastium vulgatum.* Graphs showing increase in (1) length, (2) breadth, and (3) thickness of *Cerastium* leaves with increase in concentration of NaCl.

The same general features were observed in the experiment with *Cerastium* plants, but in this case a concentration of 1/500 NaCl was the greatest tolerated. The plants watered with 1/500 NaCl, however, showed a very marked increase in leaf dimensions and a similar decrease in the amount of chlorophyll present. No structural differences were shown by the plants, but as the salt increased they showed more vigorous growth, with a great increase in height, and the leaves became much larger and to a certain extent more succulent. No effect on hairiness was observed.

TABLE 2.—Mean values of length, breadth, and thickness of *Cerastium* leaves in various concentrations of NaCl.

	Control. cms.	1/2000 NaCl. cms.	1/1000 NaCl. cms.	1/500 NaCl. cms.
Length	1·85	2·38	2·91	3·41
Breadth	0·805	0·96	1·11	1·31
Thickness . . .	0·0585	0·0627	0·0650	0·0669

The question arises as to whether the increase in leaf surface involves an increase in the total number of stomata, or whether the same number are simply spread over a larger area. The number of stomata on the under epidermis of the leaves from the control *Stellaria* plants, and from the large, fleshy leaves of those watered with 1/100 NaCl have been compared. A number of readings of each have been taken, and it was found that the average number of stomata on the leaves of the control was two and a-half times as great as on the 1/100 NaCl leaves. The area of the 1/100 leaves, however, was approximately only twice as great as that of the control leaves. If the number of stomata were constant on the leaf independently of its size, the ratio of the salt plant to the control plant would have been as 5:2·5 stomata per sq. mm. The actual ratios are 5:2; that is, there is an actual diminution in the total number of stomata. The net result will be a decrease of 60% of the normal value in the average transpiration rate.

Conclusion.

From the above results it is apparent that the direct action of sodium chloride in solution on certain mesophytic plants is to increase not only thickness, but also length and breadth of leaves, and that up to a concentration which is lethal for a specific plant, there is a correlation between osmotic concentration and leaf dimensions. The increase in succulence accompanied by a reduction in the total number of stomata and, consequently, a decrease in transpiration, favours the conservation of water by the plant, and this is necessary as the high osmotic concentration of the salt in the soil retards absorption by the root system.

Summary.

1. Seedlings of *Stellaria media* and *Cerastium vulgatum* were grown in soil watered with solutions of varying concentrations.

2. As the concentration of the salt was increased the leaf dimensions were found to increase. The highest concentration of NaCl which could be added was 1/500 for *Cerastium*, and 1/100 for *Stellaria*.

3. The number of stomata per sq. mm. of leaf surface of *Stellaria* was found to be diminished in high concentrations of NaCl. This was not merely a mechanical effect due to increase in leaf surface, because the total number of stomata was also reduced, thus reducing transpiration.

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[Proc. Roy. Soc. Victoria, 42 (N.S.), Pt. II., 1930.]

Art. XII.—*The Palisade Cells of the Seed Coat of Albizzia lophantha.*

By F. G. ELFORD, B.Sc.

(Research Scholar, Botanical Department, University of Melbourne).

(Communicated by Dr. E. I. McLennan.)

[Read 14th November, 1929; issued separately 7th March, 1929.]

Introduction.

This paper deals with the sectioning and staining of the seed coat of *Albizzia lophantha,* and the structure of the epidermal palisade cells. The first problem was to soften the seed coat to enable suitable sections to be cut with the microtome. Other problems followed, namely, the question of a suitable stain, the structure of the palisade cells, and the nature of the globule contained in these cells.

The work has been carried out in the Botanical Laboratory of the Melbourne University under the supervision of Professor Ewart, to whom I wish to express my thanks for his assistance and untiring interest, and for making available for me the facilities for the completion of this work. I take the opportunity of thanking Dr. McLennan, of the School of Botany, for her keen interest and valuable assistance.

General Structure of the Seed Coat, and Previous Work on this Subject.

The seed coat of *Albizzia* is composed of the following parts, the character of the cell wall of each part being determined by the chlor-zinc-iodine test:—

1. A cuticle composed of pure cutin.
2. An epidermis of palisade cells—the macrosclerids or Malpighian cells of Pammel (7)—the outer portion of which is cuticularised (the cellulose wall being impregnated with cutin), and the inner portion is composed of unaltered cellulose.
3. A row of hour glass cells—the osteosclerids of Pammel—which are very characteristic of Acacias.
4. Inner layers of integument—the nutrient layer of Pammel—the cell walls of which are composed of hemicellulose.

Rees (8) concluded from an examination of hand sections of the seed coat, that there are two layers of palisade cells instead of one, as is the general rule in Acacias. No reference was made to the globules, but it appears from the diagrams that these were interpreted as intercellular spaces between the two layers of palisade cells (8, pl. lxxxi.).

The Sectioning, Maceration, Staining, and Microscopic Study of the Seed Coat.

The main difficulty in sectioning the seed coat was to soften it, and to retain this softness during fixing and embedding. The first attempts at fixing the material by means of Flemming's fluid and Bouin's formal fixative were failures. The material became very hard and brittle, and difficult to section. Various methods of softening were tried, e.g., soaking the seeds in chloroform, caustic potash, and sulphuric acid, at various temperatures, and for various lengths of time. Then the seed coats were embedded in paraffin in the usual manner, using both the glycerine and spirit methods of dehydration. No improvements on the first methods were noted.

Finally, it was found that by soaking the seeds for at least one week in hydrofluoric acid, and then quickly transferring them through the alcohols and chloroform to paraffin, very satisfactory sections could be obtained. Sections of a thickness of 5μ-10μ were cut, and from these the structure of the seed coat could be clearly defined.

By soaking the seeds in a concentrated solution of caustic potash for 5-6 days, and by teasing out the frayed seed coat resulting from this treatment, single palisade cells were isolated. Single cells were also isolated by boiling the seed coat in a solution of concentrated nitric acid and chromic acid for 2 minutes, and also by boiling in aqua regia for 5 minutes. From an examination of the single cells thus isolated, the relation of the globule to the palisade cell, as determined from sections, was confirmed.

Various stains were tried (Chamberlain (1)). These included Iron alum-haematoxylin and Erythrosin, Ruthenium red, Safranin and Light green, and Gentian violet. Of these, Safranin and Light green used in combination was the most satisfactory, the Safranin staining the cuticularised parts of the seed coat whilst the Light green stained the unaltered cellulose, and thus differentiated the parts of the testa.

From a study of these sections, and of the single cells isolated by maceration, the structure of the testa is seen to differ from the description given by Rees in the following points:—

1. Forming the epidermal layer there is one layer of palisade cells, and not two.
2. A highly transparent globule exists in the cavity of these cells just beneath the limit of cuticularisation.
3. A layer of hour glass cells separates the epidermis from the inner layers of the integument.

Hand sections, where no fine degree of thinness can be obtained, might suggest two layers of palisade cells, and owing to their high transparency, the globules could be overlooked, or might appear as intercellular spaces between the two layers of cells, especially if the sections were not stained.

1. The Cuticle and Epidermal Palisade Layer.

The cuticle, as seen in thin section, is well defined. The outer ends of the palisade cells can be clearly seen. The inner part of the cuticle appears to be laminated, suggesting that cutin has been deposited in successive layers on the outer ends of the palisade cells. (See Fig. 1.)

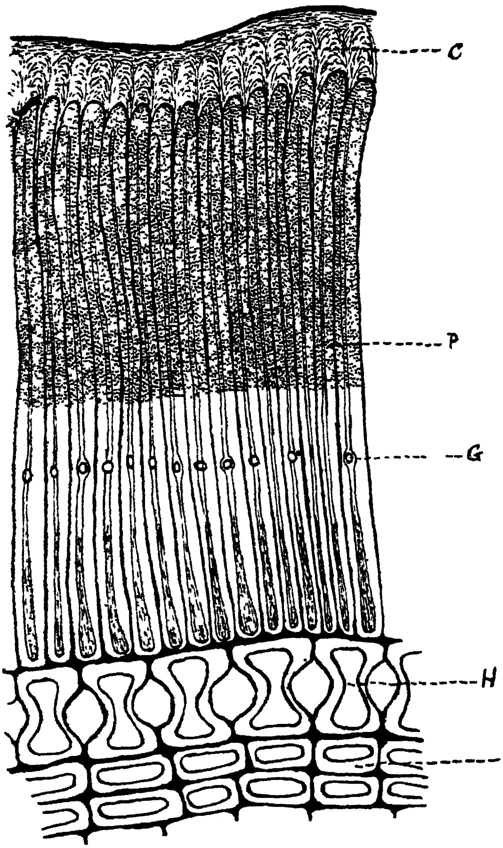

Fig. 1.—Transverse section of portion of the seed coat of *Albizzia lophantha.* C. cuticle; P. palisade cells: G. globules; H. hour glass cells; I. inner layers of the integument. ×300

The epidermal layer is made up of one layer of long narrow palisade cells. In this respect, *Albizzia* is not an exception to the rule among the Acacias. These cells are packed closely together, and at the inner end they abut on to the hour glass cells. The cell cavity is long, and although it narrows and is difficult to see in the outer portions of the cells, it is quite clearly seen at the inner ends, where it widens out, and is filled with protoplasmic contents,

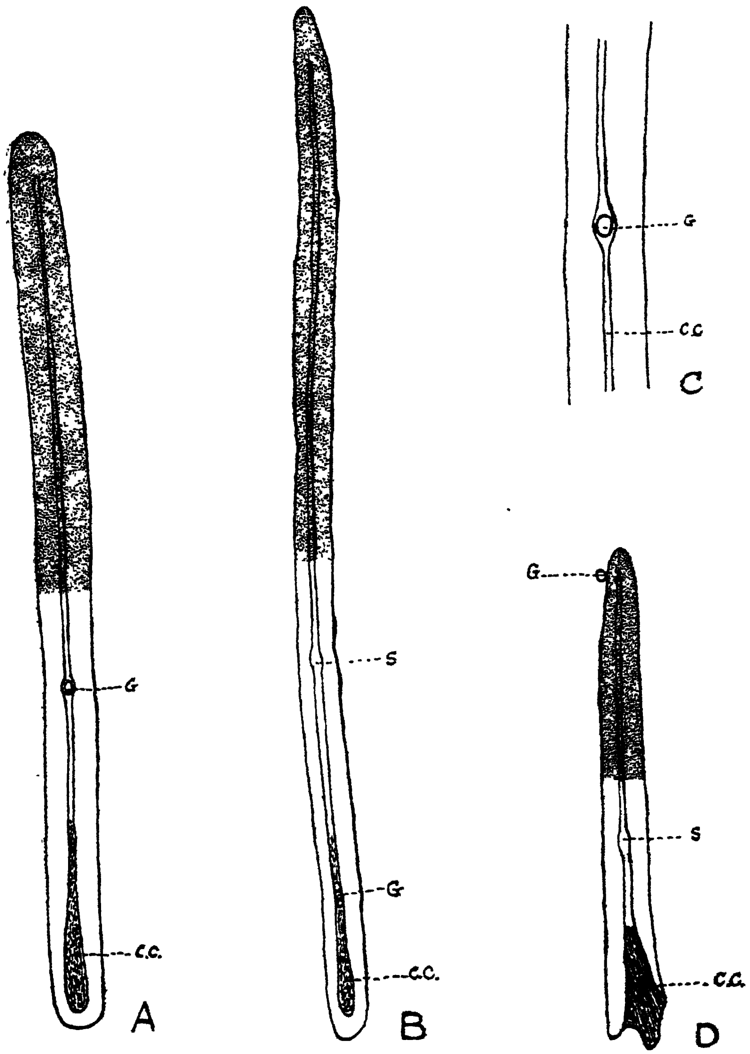

FIG. 2.—Palisade cells of *Albizzia lophantha*, drawn with the aid of a camera lucida. The dotted area represents that part of the palisade cell which is cuticularised.

A. Single palisade cell isolated by maceration. G. globule in its normal position; C.C. cell cavity with protoplasmic contents ×500.

B. Single palisade cell isolated by maceration. S. space in cell cavity previously occupied by globule; G. globule broken into three parts as a result of maceration; C.C. cell cavity with protoplasmic contents. ×500.

C. Portion of a single palisade cell isolated by maceration, and drawn with the aid of an oil immersion lens. G. globule in its normal position in the cell cavity (C.C.). ×720.

D. Single palisade cell isolated by maceration. S. space in cell cavity previously occupied by the globule; G. globule which has escaped from the cell cavity; C.C. cell cavity opening to the exterior owing to a break in the cell wall caused by maceration. ×500.

which are stained by Safranin. The outer half of this cell layer is cuticularised, the cuticularisation ending abruptly, and its inner limit is marked by a sharp line running across the cells. Just beneath this, there is a line of highly transparent globules situated in the cavities of the cells. The presence of these globules in *Albizzia* has not previously been noted. (See Fig. 1.)

2. The Globules of the Palisade Cells.

The transparent globule is the most interesting part of the structure. From the sections, and single cells obtained by maceration, the globule is seen to occupy a definite position in the cell cavity—approximately the same position in each cell. (See Figs. 1 and 2*a*.) In the macerated cells this globule was often seen to be displaced and occupied various positions in the cavity. In some cases, it appeared to be broken into two or three parts as a result of maceration. The cell cavity appears to widen to accommodate this globule, and when the globule is displaced, this widened cavity is clearly visible. If the cell wall is broken, the globule escapes from the cell cavity. (See Figs. 2*b*-*d*.)

The globule presents different positions in relation to the cavity according to the depth of focus at the top of the cell above the globule, through the central line of the cell, or along the lower part of the cell beneath the globule. In the first case, the outlines of the cell cavity appear above the globule—the widening cavity showing below. In the second case, the globule is seen with the cell cavity widening to accommodate it, whilst in the third case, by focussing through the globule, the straight edges of the cavity are visible beneath. These relations may be represented by the following diagrams (Fig. 3).

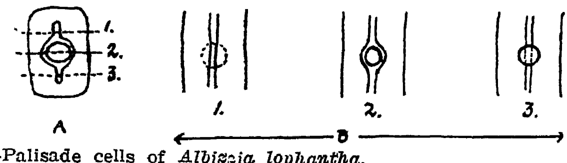

Fig. 3.—Palisade cells of *Albizzia lophantha*.
A. Transverse section; 1, 2, and 3 indicating planes of focus
B. Portions of longitudinal sections, showing the relation of the globule when focus is above it (1), through centre of it (2), and below it (3).

Following methods set out in Ewart (2), Haas and Hill (3), Lee (4), McLennan (5), and Onslow (6), a large number of microchemical tests were carried out in order to ascertain the chemical nature of the globule. On the results of the following tests it was concluded to be a globule of wax.

Stained sections were placed in the commonly known wax solvents—carbon tetrachloride, carbon disulphide, chloroform, and ether—for a period of five months, and weekly examinations were made of the material. After some time, the globules appeared to have a roughened appearance, suggesting that they were being dissolved. The action was most rapid in the sections in carbon

disulphide and carbon tetrachloride. After four months the globules decreased in size, and finally sections were obtained containing a few remnants of globules and spaces once occupied by the globules. To confirm the conclusion, arrived at as a result of these tests, that the globule was a very resistant wax, the sulphuric acid test was applied. By drawing weak sulphuric acid over the sections it was found that in untreated sections, the acid caused the cell walls to swell and finally to disintegrate. Globules were still seen in the disintegrated mass. In the case of sections treated in the solvents, on the swelling of the cell walls, the spaces once occupied by the globules were seen to close, and no trace of globules could be found in the disintegrated mass, except in one or two cases, where solution had not been complete, the remains of a few globules were found. This test proved that the globules had been slowly dissolved from the cells.

The following tests were also applied:—

1. Sections were soaked for one week in osmic acid. The cuticularised part of the seed coat was blackened and a dark line indicated the position of the line of globules. Under high magnification, the globules appeared to be discoloured on the surface. By focussing on to the top or bottom of the globules they appeared as dark dots, whilst on focussing to the centre of them, they appeared as dark rings.

2. Similar results were obtained by soaking sections for one week in Alkannin, and in Fuchsin-iodine-green.

3. When sections were examined under polarized light, the palisade layer appeared anisotropic, displaying brilliant colours. Under high magnification the globules also appeared anisotropic. Sections submitted to the wax solvents previously referred to, gave similar results, but the polarization colours were less brilliant. When sections were heated to a temperature of 95°C., by means of a hot box, the same results were noted. At this temperature, however, the globules could not be seen distinctly, suggesting that they had melted. On allowing the sections to cool the globules reappeared.

Other microchemical tests were applied for tannins, cellulose, lignin, suberized and cuticularised membranes, etc., and although some of these reagents affected other parts of the seed coat, they had no effect on the globules.

These wax globules probably serve the purpose of plugs to keep open the long palisade cells, and to add strength to the palisade layer. Being of a waxy nature, they form a very effective means of increasing the impermeability of the seed coat to water.

3. The Hour Glass Cells.

The hour glass cells, with their characteristically shaped cell wall and cavity, and with rounded intercellular spaces between them, separate the epidermal palisade layer from the inner layers of the integument. (See Fig. 1.)

Summary.

1. The seed coat of *Albizzia lophantha* can be successfully sectioned after soaking it for at least one week in hydrofluoric acid, and by transferring quickly through the alcohols and chloroform to paraffin.

2. Safranin and Light green used in combination are suitable stains to differentiate the structure of the testa.

3. There is only one layer of palisade cells forming the epidermis.

4. In the cavity of each palisade cell is a highly transparent globule. These globules appear to be arranged in a distinct line across the cells.

5. The globules are of a waxy nature. They dissolve slowly in wax solvents, are stained on the exterior by fat stains, and have a high melting point.

6. A layer of hour glass cells separates the epidermal layer from the inner layers of the integument.

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[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II., 1930.]

ART. XIII.—*On the Relationship of the Epidiorite and the Granite at Barrabool Hills and Dog Rocks, near Geelong, Victoria.*

By ALAN COULSON, B.Sc.

(With Plate VI.)

[Read 14th November, 1929; issued separately 7th March, 1929.]

Introduction.

Although the outcrops of Epidiorite (Greenstone) in the Geelong District have long been known, evidence of the relationship between the epidiorite and the associated granite has been lacking. Some time ago Dr. Summers suggested that the writer seek more evidence on the matter; the result of the work is embodied in the present paper.

The location of the outcrops of the two rocks is shown in the sketch map (Fig. 1). In this, however, relative proportions are indicated only approximately; e.g., the epidiorite at the Dog Rocks is represented as five large masses, whereas actually it occurs as a discontinuous line of boulders along the eastern flank of the hill.

The geology of the eastern portion of the map has been taken, with some simplification of the Kainozoic series, from the Quarter Sheets 24 N.E. and 24 S.E., mapped by R. Daintree in 1861-3. The geology of the western portion has been added by the writer.

Previous Workers.

The earliest published description of the epidiorite was made by Prof. Ulrich in the Exhibition Descriptive Catalogue (1).

In 1916 a local syndicate attempted to work the epidiorite of Gleeson's Hill for monumental stone, and Messrs W. H. Ferguson, J. P. Kenny, and A. M. Howitt, of the Mines Department, reported on these activities during 1916-18.

The syndicate also submitted a sample of the rock to Professor Skeats in 1916, and he gave it the name Epidiorite.

The granite of the area under discussion is identical with that of the You Yangs, which has been described by Prof. Skeats (2).

Dr. Summers in a paper (3) on the origin of some Victorian igneous rocks, introduced the problem of the relationship of the epidiorite to the granite, and put forward a theory to explain their relations. He remarked, however, that the relationship he postulated could not be stated to have been proved owing to the inconclusive nature of the field evidence then available.

The relevant parts of the above literature are discussed in the succeeding pages.

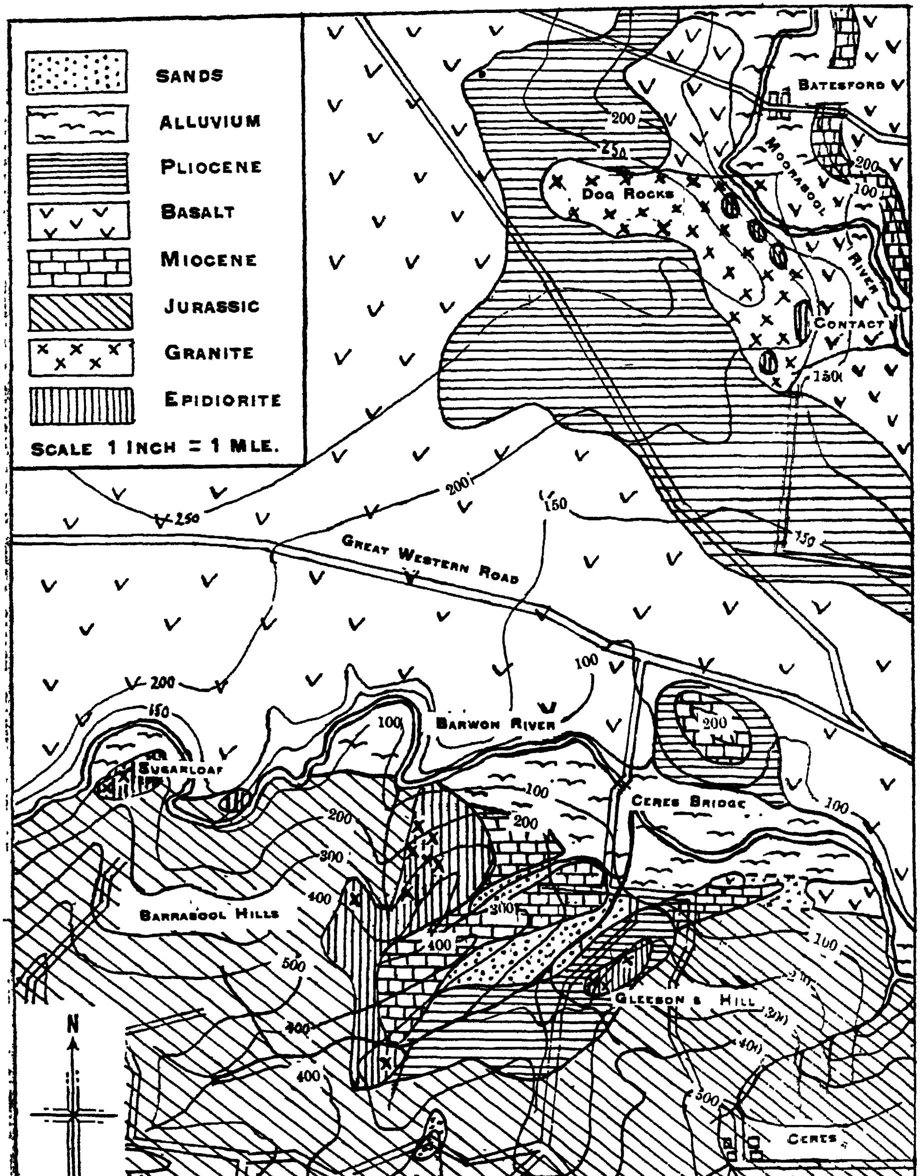

Fig. 1.—Sketch map to show location of outcrops of Epidiorite and Granite at Barrabool Hills and Dog Rocks in the Geelong District.

Lithology.

Epidiorite.

The typical epidiorite is a massive igneous rock, dark green in colour, very hard and tough. The unexpected hardness of the stone caused the syndicate to give up their project. A suitable quarry face could not be obtained, and the rather close rhomboidal jointing in the rock produced blocks unsuitable for working. Weathered blocks show an irregular hackly surface due to the removal of felspathic minerals by atmospheric weathering. A small amount of pyrite is disseminated throughout the rock, and thin incrustations of pyrite and molybdenite can occasionally be seen on some blocks. Alteration of the pyrite has led to the deposition of iron oxides in certain joints. Mr. J. P. Kenny, of the Mines Department, bearing in mind the similarity of this rock to the Western Australian greenstones, had an analysis made of the iron oxides. They showed a trace of gold and silver, but no platinum.

The rock has been called variously Trap, Hypogene, Gabbro Rock, Diallage Rock, Greenstone and Diabase, but in view of the present mineralogical composition it is best termed Epidiorite.

Prof. Ulrich (1) described the rock as "a coarsely crystalline granular mixture of light-green Labradorite and of a dark-green augitic mineral which according to its lustre and cleavage is Diallage." In corroboration of this determination, he quoted a chemical analysis by Mr. J. Cosmo Newbery: "40·06% is soluble in HCl, and the analysis of this portion proves it to be Labradorite, whilst the insoluble portion comes very near the mean composition of Diallage."

The petrographic description by Prof. Skeats reads: "Specimen 1843 (S 4664) from Ceres, near Geelong.

"*Hand Specimen.*—Rock dark in colour, of medium coarse texture. S.G. 2·93. One face has been polished. It takes a fair polish, but is not quite uniform owing to variation in the hardness of the constituent minerals.

"*Microscopic Characters.*—The rock originally consisted of crystals of Augite and Plagioclase felspar. It has been almost completely recrystallized, owing to stress by dynamic metamorphism, but does not show foliation. It now consists of the following minerals: Partially altered Plagioclase showing remains of lamellar twinning, Plagioclase completely altered and recrystallized to a granular aggregate of Albite felspar and Zoisite. The Augite in places remains partially unchanged, but for the most part is recrystallized as platy and fibrous masses of secondary Hornblende (Actinolite and Tremolite) and Chlorite. The original texture of the rock was probably medium grained, and it was probably a diabase or dolerite. In its present metamorphic condition it is perhaps best described as an Epidiorite."

Three microscopic sections of the normal type epidiorite examined by the writer agree closely with the above description by Prof. Skeats. Two were from the Dog Rocks and one from the Barrabool Hills. Partial recrystallization is universal throughout the normal epidiorite; uralitization of the original augite and diallage has converted them into actinolite and hornblende; saussuritisation of the plagioclase has produced a mosaic of albite, zoisite and epidote; chloritisation of the ferromagnesian minerals has also occurred, probably after the uralitization. Minute crystals of pyrite occur, rarely, in the normal rock.

A characteristic feature of the epidiorite in mass is the variation in texture. One block may show several bands, each of different grain-size, with sharp junctions between them. Even the finest grained material, however, is definitely massive igneous; no sign of tuffaceous character can be seen in a microscopic examination of this fine-grained material. The bulk of the rock is medium-grained, but varies from very fine to very coarsely crystallized rock, some of the amphiboles in the latter being up to 4 inches long. Thin irregular veins of white felspathic minerals traverse the epidiorite, and jointing has often occurred along these.

Granite.

The granite of the Geelong district is limited to one type, a true acid granite, which outcrops at Maude, You Yangs, Dog Rocks and Barrabool Hills. Its petrography has been studied by Prof. Skeats (2). It is a pink-coloured coarse-grained granite with porphyritic felspars, and under the microscope is seen to consist of abundant quartz, orthoclase and subordinate plagioclase, biotite and some muscovite. The rock is susceptible to attack by atmospheric weathering agents, and crumbles away to coarse sand. No trace of recrystallization can be observed, and this is significant because the epidiorite is characteristically recrystallized.

Dr. Summers (3) has classed this granite with those of Cape Woolamai, Gabo Island and Mount Buffalo in his "Alkaline Group," of probable post-Ordovician and pre-Devonian age.

Theories of the Relationship.

Three possibilities exist as to the relationship, viz.—

A.—Granite intrusive into Epidiorite.

B.—Granite and Epidiorite the differentiation products of one magma.

C.—Epidiorite intrusive into Granite.

Theory A.—The epidiorite is regarded, according to this theory, as roof-pendants on stocks of the underlying granite bathylith, to the upward movement of which the metamorphic changes in the epidiorite are ascribed.

This view, first proposed by Dr. Summers, is the one generally held, at any rate for the Barrabool Hills outcrops, and the result of the writer's work has been to confirm it.

Theory B.—This conception of the relations was advanced as an alternative by Dr. Summers (3). Noting that at Gleeson's Hill in the south a granite porphyry dyke is intrusive into the epidiorite, while at the Dog Rocks the epidiorite, in the form of what he regarded as veins, seemed to be intrusive into the granite, he suggested that "the two rocks were derived from a common magma by complementary differentiation, and that the basic differentiation product was intruded to the south and the acid portion to the north. At the time of intrusion the differentiation was not quite complete, and in the southern area the residual acid portion separated out and was intruded through the basic portion in the form of a dyke."

The "veins" of epidiorite at the Dog Rocks are not in contact with the granite, but are merely lines of boulders passing between boulders of granite, and no conclusion can safely be drawn from this source. The writer was fortunate in discovering a small dyke of granite intruding the epidiorite at the Dog Rocks, so that here, as well as at the Barrabool Hills, the granitic rock is intrusive.

Theory C.—After a hurried examination of the outcrop at Gleeson's Hill in 1918, Mr. A. M. Howitt, of the Mines Department, described the epidiorite there as "an elongated boss-like intrusion" into the granite. If this were correct, one would expect to find that the granite had been metamorphosed and that the epidiorite was the fresh rock, but as shown in the microscopic descriptions, the epidiorite has suffered from these changes while the granite has not.

It appears clear, therefore, that the granite is definitely intrusive into the epidiorite in both localities. The additional evidence obtained by the writer is interpreted in the light of this conclusion, and finally the origin and age of the epidiorite is discussed.

Additional Evidence.

1. *Dyke of Granite at the Dog Rocks.*

This dyke occurs in the outcrop marked "Contact" on the map. It is about 5 inches wide, and passes at a steep angle through a boulder of epidiorite some 4 feet across, as shown in Plate VI., Fig. 4. The granite is fine-grained on either edge, but in the centre it is coarse-grained to pegmatitic, due no doubt to concentration of mineralizers there during injection. The dyke extends downwards into the main granite mass of the Dog Rocks, and clearly has intruded the epidiorite. The junction between the two rocks is quite sharp. A microscopic section of the junction of the two rocks shows that "contact" minerals are absent; the junction is quite sharp. Some limonite is present along the

junction as a product of weathering. The granite is the true acid type, with angular quartz, abundant felspars—orthoclase and subordinate plagioclase, biotite and a little muscovite. The epidiorite of this slide does not differ very much from the normal type. It consists of secondary hornblende, secondary felspar—albite, and zoisite, remains of the original augite and plagioclase, and chlorite.

The fact that the intrusion of the granite has not caused any marked departure from the normal character in the epidiorite shows that the thermal metamorphic effects were negligible even close to the granite. We must therefore seek another explanation of the partial recrystallization which is common throughout the epidiorite. It seems most probable that dynamometamorphism is the cause. The uralitization (paramorphic conversion of pyroxene to amphibole) is a feature characteristic of dynamometamorphism.

2. *Change from Granite to Granite Porphyry.*

In the Barrabools the best opportunity of studying the two rocks *in situ* is in the northern part of the large central outcrop. Here the epidiorite caps the hills as a long "reef" of boulders *in situ*, and appears to be about 100 feet thick. On the western slopes, where denudation has been most effective, the underlying granitic rock has been exposed as helmet-shaped boulders, about a dozen in number. A change in character of the rock in these boulders occurs as we ascend. At the foot of the hill, the rock is typical coarse-grained pink granite, with porphyritic felspars. Higher up it becomes a granite porphyry, showing two distinct generations of crystals, and is a parti-coloured rock, the felspar phenocrysts being pink and the groundmass of a grey colour. Just below the base of the epidiorite, the rock resembles a granodiorite porphyrite, the felspars being now white in colour, and the groundmass dark-grey.

This granite porphyry is also seen in the other Barrabool Hills outcrops, especially on the upper levels, and seems to be between the granite proper and the epidiorite. It is not present in the Dog Rocks outcrop of granite. The explanation of this porphyritic structure in minor intrusions is stated by Hatch (4) to be due to two phases of consolidation of the granitic magma: slow formation of phenocrysts in the abyssal magma followed by rapid crystallization of the interstitial liquid when the released semi-crystallized magma came into contact with the cool country rock (epidiorite) during its upward movement by magmatic stoping. The darker colour of the granodiorite porphyrite is possibly due to marginal assimilation of the epidiorite.

3. *Variation of texture in the epidiorite.*

This phenomenon, noted before, may be due to two causes. The dolerite or diabase from which the epidiorite has been derived

may have been extruded as a succession of lava flows, each crystallizing somewhat differently, producing the banded structure. These "bands" are only a few inches wide, and cannot be traced out as definite beds in the rock, as one would be able to do with tuffaceous beds.

Alternatively the structure may be due to recrystallization and partial flowage owing to stress by dynamometamorphism. This is not such a likely explanation, although pressure effects undoubtedly account for the occasional slickensided surfaces of amphibole on some of the epidiorite blocks, and also for the incipient foliation and orientation of minerals shown by the finer grained material. If the banding of textures were due to dynamometamorphism the development of foliation would be much more marked. The typical epidiorite, according to Hatch (4, p. 397) shows uralitization without the development of foliation.

4. *Incrustations of Pyrite and Molybdenite.*

The incrustations of sulphide minerals are very thin, and their location in joint planes points to a pneumatolytic or hydrothermal source, presumably the granite. "An impregnation by pyrite is always associated with the formation of greenstone, and pyrite is always secondary in saussuritized and uralitized rocks." (Weinschenk, 5, p. 151).

5. *Felspathic Veins in the Epidiorite.*

Irregular veins of white felspathic minerals traverse the boulders of epidiorite. Under the microscope the felspar proves to be a recrystallized albite-zoisite mosaic, probably due to the dynamometamorphism of the rock, when partial fusion under pressure would result in the segregation of the different minerals, and their recrystallization in veins.

6. *Coarsely crystallized Epidiorite, containing quartz, etc.*

Several slides made of this material yielded some very interesting information regarding the mineral changes. They are therefore described in some detail.

No. 2. Macroscopic.—Very coarse-grained epidiorite, with large crystals of quartz and felspar, but very little ferromagnesian minerals. George's Hill, central outcrop, Barrabool Hills.

Microscopic.—The most abundant mineral is secondary quartz, with undulose extinction. Next comes analcite, completely isotropic, in colourless compact masses. The groundmass consists of a granular mixture of quartz, recrystallized felspar, and chlorite. A small amount of augite with peripheral secondary hornblende is present.

No. 3. Cut from the same piece as No. 2.

Microscopic.—The secondary quartz in this section has corroded the edges of the hornblende and chlorite, and is evidently

an admixture from an outside source. Analcite, secondary hornblende and chlorite are present. In one part there is a good example of uralitization—a crystal of diallage surrounded by secondary hornblende. Minute crystals of accessory ilmenite are scattered through the section.

No. 4. Macroseopic.—Coarse-grained epidiorite, George's Hill, central outcrop, Barrabool Hills.

Microscopic.—Secondary quartz is abundant; it is evidently a later admission to the rock, for it has corroded the portions of the other minerals nearest it. A large crystal of labradorite is remarkable for its freshness and broad lamellar twinning. That portion of it nearest the quartz is, however, recrystallized to albite and zoisite. Secondary actinolite, in the form of large crystals and clusters of fibrous needles, is common, and remnants of diallage crystals can be seen enclosed by the actinolite. Several patches of dark-coloured minerals proved to be ilmenite (partly altered to leucoxene) and a brown mineral possessing the optical properties of micaceous ilmenite.

No. 5. Macroscopic.—A specimen of normal epidiorite traversed by small veins of quartz. Gugger's Hill, central outcrop, Barrabool Hills.

Microscopic.—The commonest minerals are secondary actinolite and fibrous secondary hornblende, both formed by the uralitization of augite, some of which remains. The veins of secondary quartz traverse the section, and have corroded the edges of the ferromagnesian minerals. Analcite is present in small amount, also chlorite, pyrite and ilmenite.

The study of these sections reveals two additional mineral changes, silicification and analcitisation, resulting in the formation of secondary quartz and analcite respectively. These changes involve the introduction of new material from without, and the source is probably the juvenile waters of the granitic magma. Probably the bands of coarse-grained epidiorite correspond to joint planes in the original rock, and along these travelled the mineralized waters from the intruding granite. Partial solution of the rock on either side of the joint plane would occur, and the whole would slowly crystallize to form the coarse material now seen.

Review of the Metamorphic Changes.

In the normal epidiorite, the changes have been induced by dynamometamorphism, and include uralitization, saussuritization, epidotisation, and chloritisation. It is reasonable to assume that the great pressure which caused the changes was due to the upward-moving granite. The fracturing of the epidiorite would open up passages for the circulation of gases and thermal waters, and thus facilitate the hydrothermal changes, silicification and analcitisation, which took place in those passages. The sulphide minerals would form in the cracks more remote from the granite.

Age and Probable Origin of the Two Rocks.

Boulders both of epidiorite and of granite occur in the Jurassic basal conglomerate, which is exposed in a river cliff on the east bank of the Barwon, some two miles east of Ceres Bridge. They are both therefore pre-Jurassic in age.

Professor Skeats (2) has demonstrated that at the You Yangs granite of the Alkaline Group is post-Lower Ordovician, since it has intruded and metamorphosed sediments which are probably of that age. The Alkaline Group is regarded (3) as being older than the Victorian granodiorites, which are classed as Devonian. The granite must therefore have been intruded in the post-Lower Ordovician, post-Upper Ordovician, or post-Silurian orogenic periods.

The epidiorite, having been intruded by the granite, is obviously older than the latter, and its age is best arrived at by analogy with similar Older Palaeozoic rocks. A very good correlation can be made on field relations, lithological facies and mineral changes, between the Geelong epidiorite and the widespread Heathcotian (Upper Cambrian) series, which outcrop at Heathcote (5), Monegetta and Lancefield (6), Howqua River (7), Tatong (8), Dookie and Mt. Stavely.

The Heathcotian series of basic igneous rocks, diabases in part, have suffered albitisation, silicification, chloritisation, uralitization, formation of carbonates, and the development of the mineral lawsonite. There are associated with the diabase conformable beds of submarine tuffs, cherts and black slates. Professor Skeats has demonstrated that the diabases represent Upper Cambrian submarine lavas, which were succeeded by tuffs in which trilobites and *Protospongia* spicules of Upper Cambrian age have been found, and then by true sedimentary beds in which Lower Ordovician fossils occur. The tuffs have been silicified by metasomatic action, and are now cherts. The albitisation is possibly due to the absorption of sodium from the sea-water. Pillow-lava structure can be seen in places.

The Geelong epidiorite is exclusively igneous; nothing to correspond to the tuffaceous and sedimentary beds of the type area is present. For this reason fossil evidence of age is wanting. But the mineral changes are very similar to those experienced by the Heathcotian diabases. The analcitisation noted in some of the epidiorite may be due to the action of sea-water, but other common spilitic characters are absent, so that the analcite may have come from magmatic waters.

The chemical analyses (1) and (3) of the two rocks show certain differences; the epidiorite averages 2 or 3% higher in CaO and MgO than the Heathcote or the Howqua River diabase, but is 5% lower in iron oxides. However, these differences might be expected in rocks so widely separated in distance.

There is no other Lower Palaeozoic rock in Victoria with which a correlation can be made, and on the whole it appears best to class the epidiorite with the Heathcotian.

It has been suggested that the Heathcotian lavas formed an extensive sheet in Victoria, and that the outcrops now exposed represent anticlinal ridges in this sheet. Thus the Colbinabbin Range near Heathcote is pictured as an eroded anticlinal ridge, and the fact that if the axis of this range were produced southwards, it would pass through the Geelong outcrops of epidiorite, has been thought to indicate some relation between the two areas. Bearing this in mind, the writer made a careful search of the You Yangs, which would also coincide with the axis, to see if anything of the nature of diabase or epidiorite occurred there. A few blocks of a very dark rock, slightly greenish, were found, but they proved to be a differentiation from an unrecorded dyke of felspar porphyrite, about 20 yards wide, which runs for about 1½ miles through the middle of the granite mass. A microscopic examination of the greenish rock showed it to be a dolerite, quite fresh and without any sign of recrystallization. This negative evidence regarding the anticlinal ridge inclines one to the belief that the Geelong outcrop, at least, is a flow of lava from a vent independent of the Heathcote area, although the magmatic basin from which the lava came was probably connected, in depth, with all the vents.

There is no absolute evidence that the epidiorite was originally extruded as a submarine lava, and the absence of associated sediments seems to indicate a possibly terrestrial flow.

Conclusion.

On the evidence presented, the epidiorite must be regarded as a Heathcotian (Upper Cambrian) extrusion of massive dolerite or basalt, not necessarily spilitic in character, and possibly local in extent to the Geelong district. During the interval between the Lower Ordovician and the Lower Devonian the rock suffered dynamometamorphism, resulting in partial recrystallization throughout, and was also intruded and probably uplifted by an acid granite of the Alkaline Group. Hydrothermal action was more pronounced than thermal metamorphism during this intrusion, and caused the formation of the bands of coarsely-crystallized material.

Denudation since the Palaeozoic has removed a great deal of the epidiorite, so that now the rock outcrops as roof-pendants on the granite.

Acknowledgments.

I received much valuable advice during the progress of the work, particularly in the microscopic determinations, from Associate-Professor H. S. Summers, D.Sc., and my sincere thanks are

Fig. 1.

Fig. 2.

Fig. 3.

A.C. photo

Fig. 4.

Epidiorite and Granite. Geelong, Victoria.

due to him for this help, given at a time when he was particularly busy. The staff of the Geology School also assisted me in numerous ways. To Mr. G. B. Hope, B.M.E., of Geelong, I am especially grateful for the encouragement and criticism he has at all times afforded me.

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Explanation of Plate VI.

Fig. 1.—Typical helmet-shaped boulder of granite, surrounded by fallen blocks of epidiorite, Sugarloaf Hill, Western Barrabool Hills.

Fig. 2.—Epidiorite Boulders, on north end of George's Hill, central outcrop, Barrabool Hills, showing the rhomboidal jointing.

Fig. 3.—Angular blocks of epidiorite produced by jointing. George's Hill.

Fig. 4.—Dyke of Granite passing through block of epidiorite about 4 ft. across. Dog Rocks. Outcrop marked "Contact" on map.

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ART. XIV.—*Rare Foraminifera from Deep Borings in the Victorian Tertiaries—Victoriella, gen. nov., Cycloclypeus communis Martin, and Lepidocyclina borneensis Provale.*

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(With Plates VII., VIII.)

[Read 14th November, 1929; issued separately 10th March, 1930.]

During the investigation of numerous samples of Tertiary bore-cores for the Commonwealth Government, in connection with oil research, we are meeting with large numbers of new and interesting fossils, which we propose to note and describe from time to time. The present paper includes notes of three of these forms, belonging to the larger foraminifera.

Victoriella, gen. nov.

During the examination of fossils obtained from a boring at Torquay, Victoria, in 1921, there was discovered among the microzoa a specimen supposed at the time to be related to *Carpenteria proteiformis*, but differing in the more verrucose surface-ornament and in having a different plan of growth. This particular species, which is an unattached form, was then referred to as *Carpenteria proteiformis* var. *plecte* (Chapman, 1922, p. 320). In that description, the senior author stated that "this variety [*plecte*] is much more abundant in the Victorian older Tertiary (Balcombian and Janjukian) than the type species." Upon looking up all available evidence of extensive collections of material made from the Balcombian and Janjukian series, it appears that this statement was based upon the supposition that the form was an undeveloped stage of *Carpenteria proteiformis*, which is common to both Balcombian and Janjukian.

The occurrence of this new form, which we now describe as a new genus, *Victoriella*, is very restricted. So far as we know at present, it occurs only in the basal Janjukian at Bird Rock, Torquay, from which a very fine series of tests was obtained many years ago by the late Dr. T. S. Hall, and also more lately in several deep borings in the Dartmoor district.

Family VICTORIELLIDAE, nov.

Note on the Family.—The description of the allied family Rupertiidae, as defined by Cushman, runs as follows: "Test in the early stages, trochoid, attached by the dorsal side as in *Cibicides,* later extending upward from the base of attachment, still keeping a loose spiral; wall calcareous, coarsely perforate; aperture either at the inner margin of the chamber or becoming terminal or rounded, often with a neck or lip." This present genus, *Victoriella,* in conjunction with *Eorupertia,* is separated from the family Rupertiidae by its non-adherent condition throughout life, by the absence of a definite spiral arrangement of the chambers, and in the more or less slit-like aperture which, in *Carpenteria* and allied forms, has a tendency to assume a tubular neck.

Genus **Victoriella**, gen. nov.

Description of Genus.—Test free, consisting of a more or less conoidal aggregate of inflated chambers, either alternating or spirally coiled, chambers not numerous. Surface granulated, the tubercles surrounded by the coarsely tubulated shell-wall. Aperture sublunate and limbate. The wall of the test is apparently simple in the later portion, but in the earliest part it consists of two layers as in *Carpenteria,* and is also thicker than in that genus. The surface tubercles are more strongly papillate than those of *Eorupertia.*

VICTORIELLA PLECTE (Chapman).

(Plate VII., Figs. 1-4.)

Description of Species.—The original description of this form, previously referred to as a variety of *Carpenteria proteiformis,* runs as follows:—"It is distinguished by the great development of the earlier series of chambers, plaited together and forming almost a rotaline coil, hence the varietal name. The surface ornament is generally more verrucose than in the specific form."

Test conoidal, with inflated chambers non-adherent. Surface verrucose or granulated, the last chamber tending to become smoother. The plan of growth shows the earlier chambers to consist of a sub-spiral aggregate, the succeeding chambers increasing rapidly in size and showing either an alternate or plaited arrangement, or in other cases, having three chambers in one plane. The last chamber shows a sub-lunate to triangular aperture which is distinctly surrounded by an everted lip or flap.

Dimensions.—Length of test, 2·5 mm.; greatest width, 1·8 mm.; thickness of shell wall, 0·15 mm.; papillae average about 0·1 mm. in diam.; stolon passages approximately 4 times the diameter of the coarse tubules.

Observations.—Professors Yabe and Hanzawa (1922, p. 71) have described, under the preoccupied generic name *Uhligina,* an interesting type allied to foraminifera like *Carpenteria* and *Ruper-*

tia, but differing in some very essential characters. This genus was afterwards changed by the same authors (1927, p. 97) to *Eorupertia*. It has been shown in the description here given that the above genus *Victoriella*, whilst agreeing with *Eorupertia* in having a free test and occasionally a spiral arrangement of chambers and tuberculate surface, differs essentially in having larger and fewer chambers, a much thicker shell-wall and less pronounced hollow centre. A difference in *Eorupertia* is the less prominent and more conical non-tubulate bosses distributed in the mass of the shell-wall which in *Victoriella* stand out more prominently from the surface.

In *Eorupertia* the stolon passages are slit-like, as in *Victoriella*, but in the latter genus the aperture is modified in most cases by having a lip or rim of shell-material, forming a complete marginal boundary. It is interesting to note that *Eorupertia* is an Eocene genus from Japan, whereas the present genus seems entirely restricted to the Miocene and to a limited horizon in that formation.

Occurrence.—*Victoriella* was represented by only one specimen from the boring at Torquay, at a depth of 24 to 25 feet, whilst the specimens collected by Dr. Hall, before referred to as occurring at the base of Bird Rock, would be relatively about at the same level as the top of the bore. This, therefore, gives us a range of 25 feet of the *Victoriella* zone at Torquay.

In the Dartmoor district, where a series of bores has been put down by the Victorian Geological Survey in conjunction with the Department of Home Affairs, *Victoriella* was found at the following depths—No. 3 at 104 feet 6 inches and 107 feet; No. 4 at 84 feet; No. 5 at 28 feet to 43 feet; No. 6 at 142 to 164 feet; No. 8 at 73 and 76 feet; No. 10 at 95 and 96 feet.

We may therefore conclude, on these grounds, that this genus has a great value as a zonal indicator.

Cycloclypeus communis Martin.

(Plate VII., Figs. 7, 8; Plate VIII., Figs. 9-13.)

Cycloclypeus communis Martin, K., 1880, p. 154, pl. xxvii., figs. 1, 2, Idem, 1891, p. 4, pl. i., fig. 4. Douvillé, H., 1905, p. 445. Douvillé, R., 1909, pp. 136-138, woodcuts, figs. 12-16, pl. vi., figs, 5, 6 (microspheric form). Douvillé, H., 1911, pp. 57, 76, 77. Schubert, R., 1911, p. 97. Chapman, F., 1914, p. 293. Douvillé, H., 1916, p. 28, pl. v., fig. 5. Yabe, H., 1918, p. 19. Rutten, L., 1921, pp. 1141, 1142. Van der Vlerk, I.M., 1922, p. 30, pl. ii., fig. 8.

Cycloclypeus communis Martin var. *borneënsis* Rutten, 1914, p. 305, pl. xxiv., figs. 3-6. Van der Vlerk, I. M., 1922, p. 391.

Observations.—We have found the above species for the first time in Victoria, in the limestones of Longford, in the deep-

boring at Metung, and similarly at Darriman, whilst Mr. W. J. Parr had previously discovered a fine series of the same species at the Batesford quarries near Geelong.

This species occurs in Victoria in both the megalospheric and microspheric forms of the test (Forms A and B). The only locality where the microspheric form has occurred in the Gippsland area, up to the present, is at Longford, represented by one specimen; at Batesford near Geelong the microspheric form is not uncommon, but the megalospheric form predominates. The Victorian examples of *C. communis* in the megalospheric stage show the test to be entirely covered with small pustules, and the comparatively large central boss agrees in that character with typical specimens described by Martin from Java.

The microspheric form is well illustrated by R. Douvillé in his Madagascar specimens (op. cit., 1909). It was subsequently separated as a variety by Rutten. Yabe later regarded Rutten's *C. communis* var. *bornećnsis*, as an annectent form linking *C. communis* with *C. annulatus*.

Cycloclypeus communis ranges from the middle part of the Naintoepo Beds (Middle Miocene) to the Poeloe Balang Beds (Upper Miocene) in Borneo. A full list of extra-Australian localities for specimens is given by Van der Vlerk (1922, p. 390).

Occurrence in Victoria.—Batesford, near Geelong (Forms A and B); and the following Gippsland localities: Darriman, No. 3 Bore, at 439 feet (form A); Le Grand's Upper Quarry, South of Longford (forms A and B); and Metung at 872 feet (form A).

LEPIDOCYCLINA (NEPHROLEPIDINA) BORNEËNSIS Provale.

(Plate VII., Figs. 5, 6.)

Lepidocyclina tournoueri Lem. and Douv. var. *borneënsis* Provale, 1909, p. 74, pl. ii., figs. 16-19.

Lepidocyclina (*Nephrolepidina*) *borneënsis* Provale: Van der Vlerk, 1928, p. 23, figs. 16 *a-c*.

It is exceptionally interesting to find this Bornean species for the first time in Australia, in material obtained from deep borings and quarry sections in South-east Gippsland, Victoria.

Both externally and in thin sections, the Victorian specimens are indistinguishable from examples in the Tertiary of Borneo. The value of this species in zonal correlation has been proved in the various bores which have lately been examined in detail in connection with oil research in those localities.

From among the associated faunal constituents of the zone of *L. borneënsis* in Victoria, we may mention the following foraminifera: *Amphistegina lessonii; Carpenteria proteiformis; Siphonina australis; Cycloclypeus communis; C. pustulosus; Lepidocyclina marginata; L. angulosa; L. tournoueri; L. inflata; L. martini.*

In East Borneo the following foraminifera are found associated with *L. borneënsis: Miogypsina irregularis; Spiroclypeus leupoldi; S. tidoenganensis; Cycyloclypeus neglectus; Lepidocyclina bonarelli; L. ferreroi; L. inflata; L. planata; L. angulosa; L. dilatata* var. *tidoenganensis.*

L. borneënsis is typical of the Naintoepo and Pamaloean Beds of East Borneo.

Occurrence in Victoria.—Woodside Bore No. 5, between 44 and 87 feet, No. 6, between 93 and 121 feet; Darriman No. 3, at 439, 459, and 489 feet; Metung at 730, 872, and 873 feet; No. 1 Bore, Parish of Colquhoun North (Lakes Entrance No. 4 Bore) at 358 feet; and in Le Grand's Upper Quarry, South of Longford. All these localities are in Gippsland.

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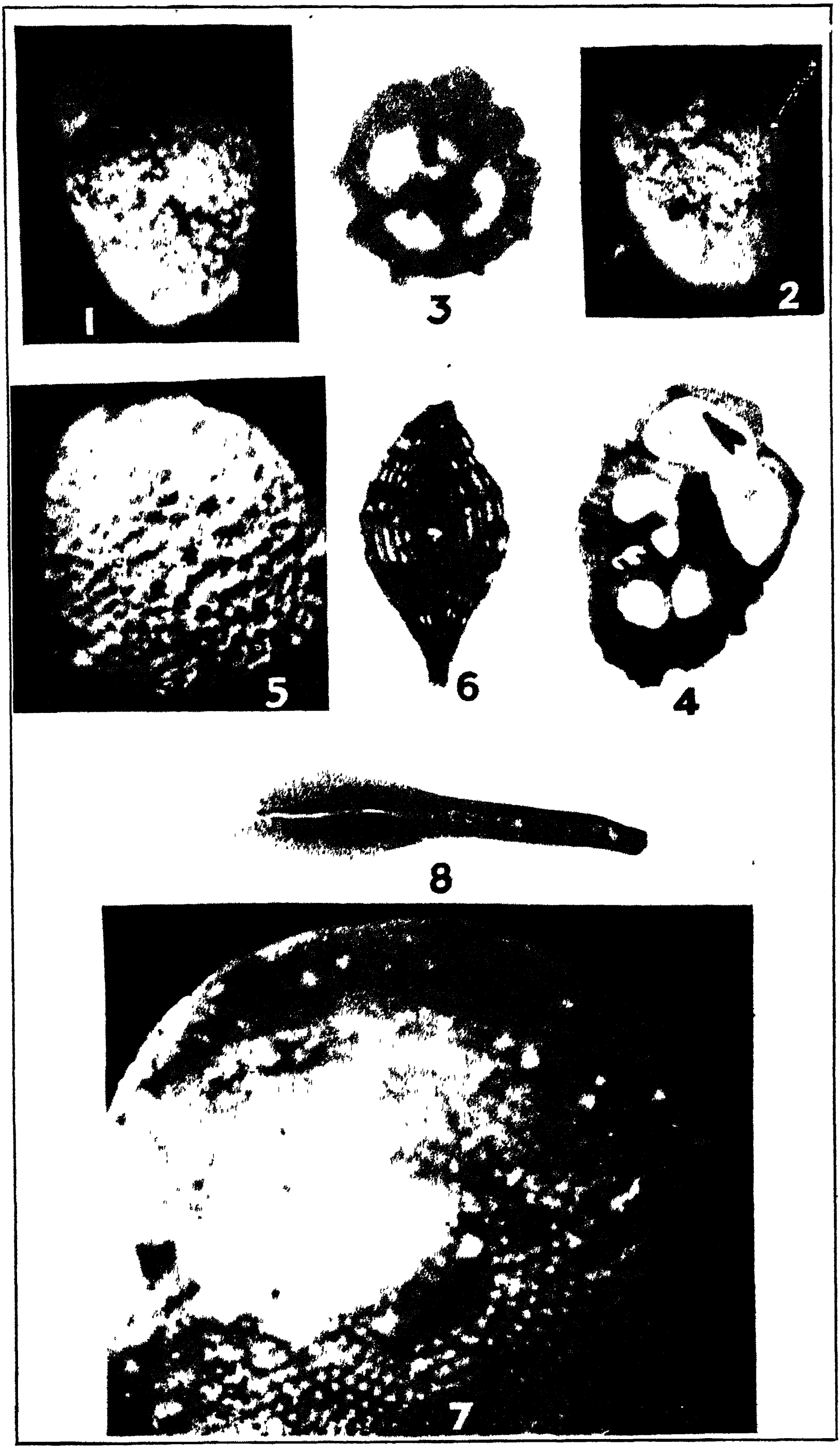
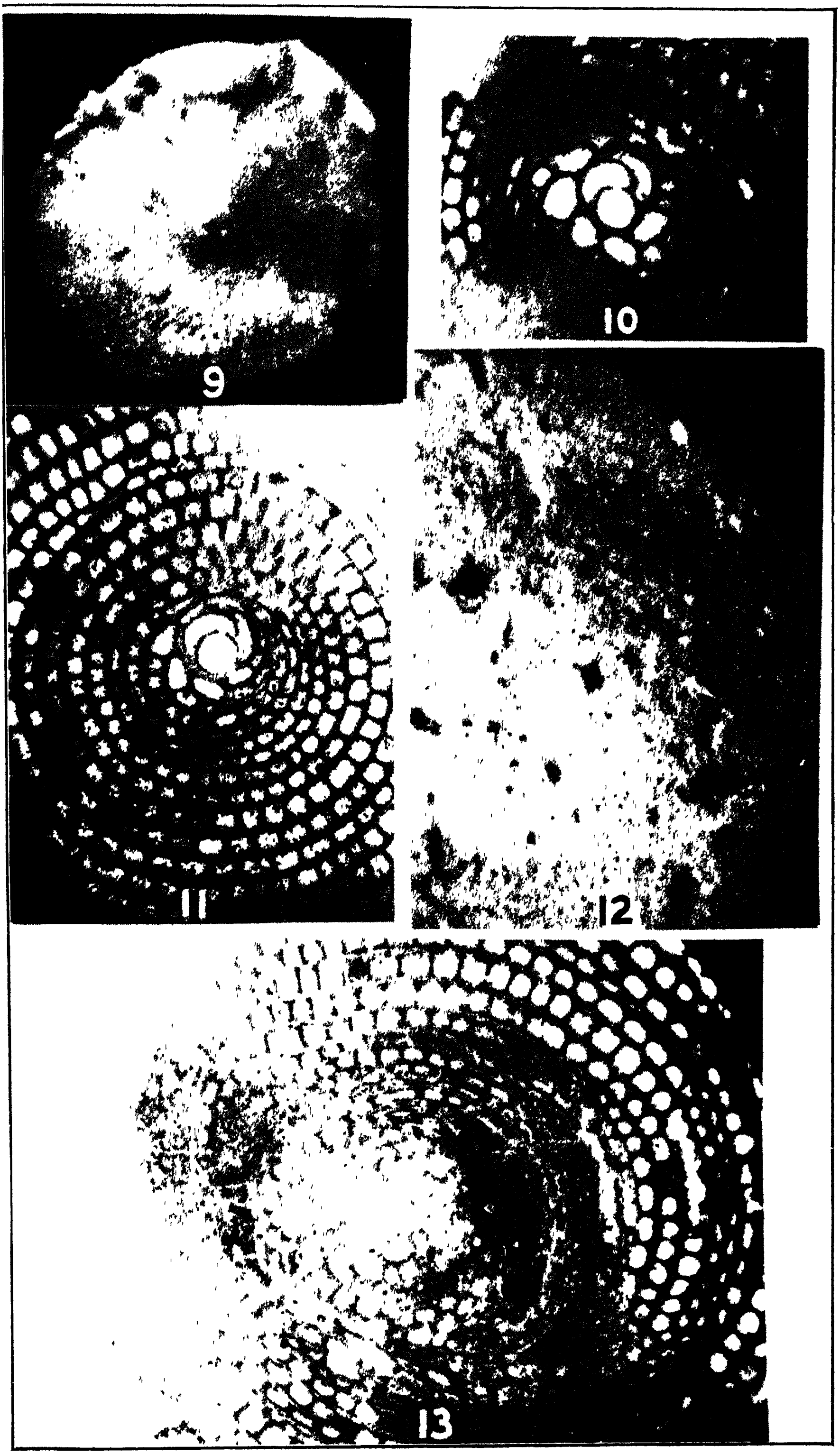


Victoriella, Lepidocyclina and Cycloclypeus.



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Explanation of Plates.

PLATE VII.

Fig. 1.—*Victoriella plecte* (Chapman). Bird Rock Cliffs, Torquay. Miocene (Janjukian). Plesiotype. ×16.

Fig. 2.—*V. plecte* (Chapm.). Another example, Dartmoor, No. 3 Bore, 104 feet 6 inches. Miocene (Janjukian). Pleisotype. ×16.

Fig. 3.—*V. plecte* (Chapm.). Horizontal section of test from Dartmoor. ×16.

Fig. 4.—*V. plecte* (Chapm.). Vertical section of test of Dartmoor specimen. ×16.

Fig. 5.—*Lepidocyclina* (*Nephrolepidina*) *borneënsis* Provale. Exterior of test. Metung Bore, 872 feet. Miocene. ×16.

Fig. 6.—*L. borneensis* Provale. Vertical section. Metung Bore, 872 feet. ×16.

Fig. 7.—*Cycloclypeus communis* Martin. Exterior of test. Form A. Le Grand's Upper Quarry, Longford, near Sale, Miocene. ×18.

Fig. 8.—*C. communis* Martin. Vertical section of test of Form A. Batesford. Miocene. ×16.

PLATE VIII.

Fig. 9.—*Cycloclypeus communis* Martin. Exterior of test, Form A. Longford, near Sale. Miocene. ×16.

Fig. 10.—*C. communis* Martin. Horizontal (equatorial) section, Form A. Longford, near Sale. Miocene. ×33.

Fig. 11.—*C. communis* Martin. Batesford. Miocene. ×33.

Fig. 12.—*C. communis* Martin. External surface of test. Form B. Batesford. Miocene. ×18.

Fig. 13.—*C. communis* Martin. Horizontal (equatorial) section, Form B, Batesford. Miocene. ×33.

[PROC. ROY. SOC. VICTORIA, 42 (N S.), PT. II, 1930.]

ART. XV.—*Some New Australian Formicidae.*

By J. CLARK, F.L.S.

(Entomologist to the National Museum of Victoria, Melbourne).

[Read 14th November, 1929; issued separately 10th March, 1930.]

Nine new species of ants belonging to the genera *Notostigma, Camponotus, Calomyrmex, Notoncus* and *Stigmacros,* all of the subfamily Formicinae, are described in this contribution. In addition Forel's description of *Camponotus* (*Tanaemyrmex*) *longinodis,* from the worker minor only, has been revised and supplemented by a description of the worker major and female.

All these genera excepting *Camponotus* are exclusively Australian. Perhaps the most interesting species in regard to distribution is *Notostigma sanguinea,* n. sp. The genus *Notostigma* was erected by the late Prof. Emery to contain two species of ants from North Queensland. At the same time he added a third from New South Wales. The species described is from Western Australia, extending the distribution considerably.

Of the five species of *Camponotus* described here the most interesting is undoubtedly *C.* (*Myrmosaulus*) *scutellus* from South-Western Australia. This is very closely related to *C.*(*M.*) *whitei* Wheeler from Central Australia. Dr. Wheeler placed his species tentatively in the subgenus *Myrmosphincta,* regarding it as probably belonging to the subgenus *Orthonotomyrmex* and allied to *C.*(*M.*) *mayri* from Madagascar. Emery later placed it in the subgenus *Myrmosaulus,* and I have for the present followed him, although the two species appear to be more correctly placed in *Orthonotomyrmex*. As pointed out by Wheeler, this is an old world group, and not known to be represented in Australia or Papua.

The species of the genus *Calomyrmex* are found, mainly, in the warmer districts of Australia, particularly in the interior. All are more or less metallic in colour, and run with great rapidity over the ground during the heat of the day. Usually they carry the gaster erect, giving them an odd appearance.

The genus *Notoncus* is well represented in most parts of the country. All have the shoulders more or less elevated. The genus *Stigmacros* contains small species having the epinotum furnished with four spines.

Sub-family FORMICINAE.

NOTOSTIGMA SANGUINEA, n. sp.

(Text-fig. 1, Nos. 1, 2.)

Worker major.—Length, 15-16·3 mm.

Blood red, antennae and legs lighter. Gaster black.

Subnitid. Gaster shining. Mandibles coarsely punctate. Head, thorax and node finely and densely reticulate, with some isolated, shallow punctures.

Hair reddish, erect, moderately abundant throughout, very short on the legs, none on the antennae. The middle and posterior tibia and tarsi with some longer bristle-like hairs. Pubescence hardly apparent except on the antennae.

Head broader than long, much broader behind than in front, the occipital border deeply concave, the sides strongly convex. Frontal carinae swerving outward in the middle, twice as long as their distance apart. Clypeus broad and convex, without a carina, the anterior border convex and feebly crenulate; there is a deep fovea at each side near the front. Eyes large, rather flat, placed near the posterior third of the sides. Scapes extending beyond the occipital border by one third of their length; second and third segments of the funiculus almost twice as long as the first, the others subequal. Mandibles large, triangular, armed with six or seven irregular teeth. Thorax twice as long as broad. Pronotum almost twice as broad as long, strongly convex on the sides. Mesonotum slightly longer than broad, feebly convex laterally; in profile the mesonotum and pronotum form an even arch. There is a wide, but not deep, constriction between the mesonotum and epinotum, the spiracles large, placed on the dorsal surface of the constriction. Epinotum as long as broad, strongly convex laterally; in profile the dorsum almost straight, the declivity abrupt, as long as the dorsum, subbordered above and on the sides. Node as long as broad in front, all four sides convex; in profile twice as high as long, inclined forward, the anterior face straight, the dorsum and posterior face united in a curve. Gaster longer than broad. Legs long and slender.

Worker minor.—Length, 11-14 mm.

Colour, sculpture and pilosity as in the major.

Head slightly longer than broad, as broad in front as behind, the occipital border produced as a short narrow neck, sides convex. Clypeus and frontal carinae as in the major. Eyes large and convex, at the posterior third of the sides. Scapes passing the occipital border by two-thirds of their length; second and third segments of the funiculus almost twice as long as the first. Mandibles armed with six strong, sharp teeth. Thorax fully three times longer than broad. Pronotum one-fifth longer than broad, twice as broad behind as in front. Mesonotum almost circular. The constriction between the mesonotum and epinotum very wide, the spiracles large, placed well on top of the dorsum. Epinotum one-third longer than broad; in profile feebly convex longitudinally, the declivity abrupt, almost at a right angle, rounded into the above. Node twice as long as broad, broader in front than behind, the sides and anterior border convex; in profile as high as long, the anterior face straight, inclined forward, the dorsum and posterior face united in a curve. The rest as in the major.

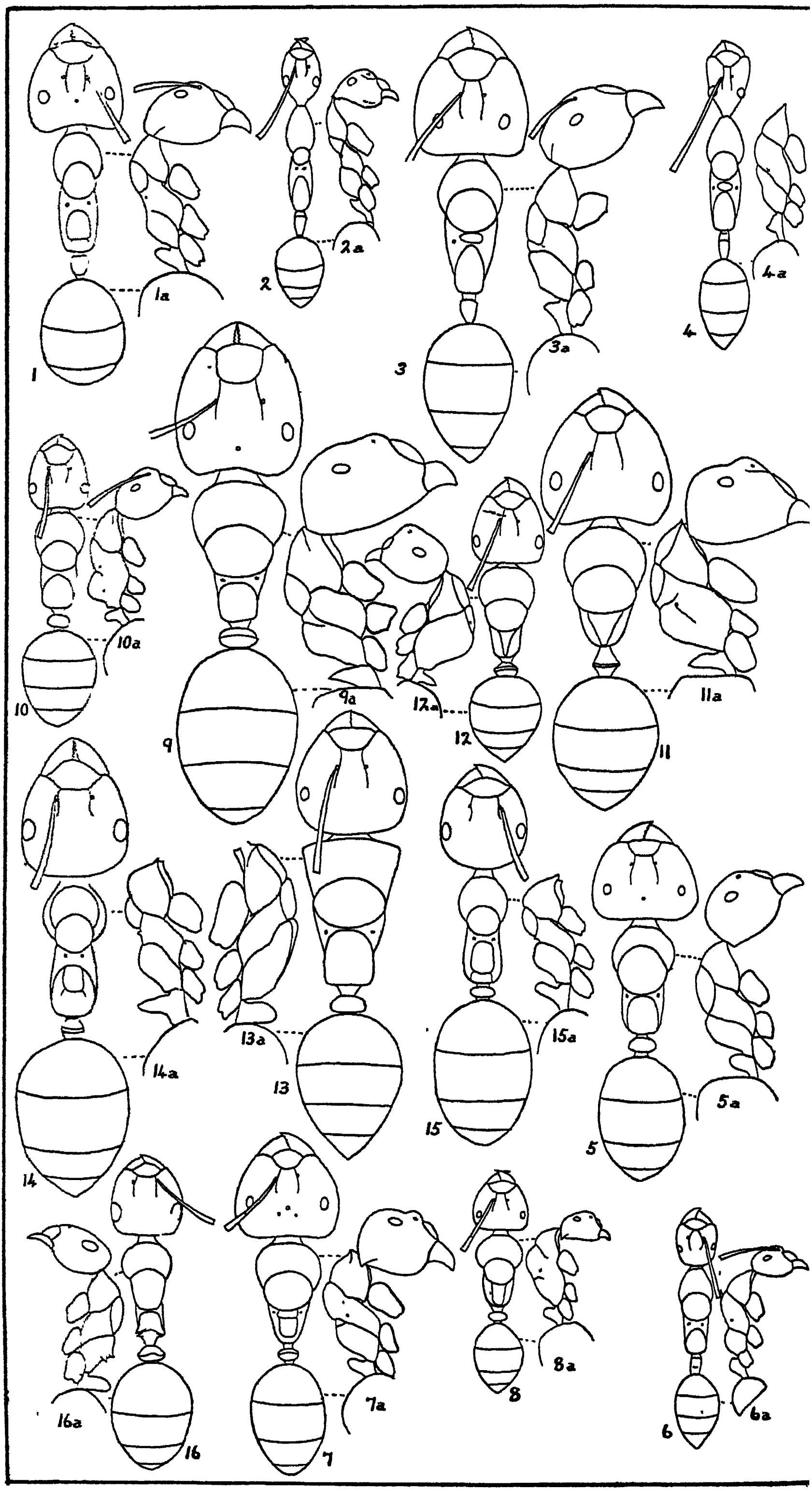
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FIG. 1.

Habitat.—Western Australia: Perth and Ludlow (J. Clark).

There are several grades between the largest and smallest workers, but they differ only in the size of the head. This species is readily distinguished from the other three species in the genus by its blood-red colour.

A large nest of this species was found under a log near Ludlow. The soldiers are very timid, and retreat into the nest on the least alarm. The workers may be seen frequently on tree-trunks during the day.

CAMPONOTUS (TANAEMYRMEX) LONGINODIS Forel.

Camponotus (*Dinomyrmex*) *subnitidus* Mayr var. *longinodis* Forel, Arkiv. for Zool., ix. (16), p. 96, 1915. ☿

(Text-fig. 1, Nos. 3, 4.)

Worker major.—Length, 16·5-18 mm.

Head and thorax brown. Mandibles and front of face black. Funiculus, legs and gaster castaneous.

Subopaque. Mandibles coarsely punctate. Clypeus and front of the face punctate-reticulate, the rest of the head, thorax, node and gaster microscopically reticulate.

Hair reddish, long and erect, rather sparse throughout. Tibia with two rows of short, sharp, bristles. Pubescence not apparent.

Head as broad as long, broader behind than in front, the occipital border straight, or very feebly concave, the sides convex. Frontal carinae diverging slightly outward behind, broadest at the middle. Clypeus broad, feebly convex, subcarinate, the anterior border produced, convex, there is a deep fovea at each side near the middle. Eyes large, placed at the posterior third of the sides. Scapes extending beyond the occipital border by almost twice their thickness; second and third segments of the funiculus of equal length, longer than the first, the others subequal. Mandibles

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FIG. 1.

1.	*Notostigma sanguinea*, n. sp. . . .	Major,	dorsal view: *a*, in profile.
2.	" " . . .	Minor,	" " *a*, " "
3.	*Camponotus* (*Tanaemyrmex*) *longinodis*, Forel	Major,	" " *a*, " "
4.	" " "	Minor,	" " *a*, " "
5.	*Camponotus* (*Myrmosaulus*) *versicolor*, n. sp.	Major,	" " *a*, " "
6.	" " "	Minor,	" " *a*, " "
7.	*Camponotus* (*Tanaemyrmex*) *postcornutus*, n. sp.	Major,	" " *a*, " "
8	" " "	Minor,	" " *a*, " "
9	*Camponotus* (*Myrmosaulus*) *scutellus*, n. sp.	Major,	" " *a*, " "
10.	" " "	Minor,	" " *a*, " "
11.	*Camponotus* (*Myrmophyma*) *tristis*, n. sp.	Major,	" " *a*, " "
12	" " "	Minor,	" " *a*, " "
13	*Calomyrmex glauerti*, n. sp.	Worker	" " *a*, " "
14.	*Notoncus hickmani*, n. sp.	Worker	" " *a*, " "
15.	*Notoncus rotundiceps*, n. sp.	Worker	" " *a*, " "
16.	*Stigmacros reticulata*, n. sp.	Worker	" " *a*, " "

large and triangular, armed with seven teeth. Thorax two and one quarter times longer than broad. Pronotum almost twice as broad as long, strongly convex. Mesonotum circular, convex above. Metanotum as a distinct raised segment, narrow, twice as broad as long. Epinotum almost twice as long as broad; in profile the dorsum feebly depressed in the middle, the declivity short, at an obtuse angle, the boundary between the two faces hardly apparent. The whole thorax evenly convex. Node one and three quarter times longer than broad, parallel, the anterior border convex; in profile higher than long, the anterior face straight and vertical for half its length, then abruptly inclined backward, the posterior face feebly convex, meeting the anterior face above, forming a sharp, pointed edge. The top is convex laterally, in *subnitidus* it is concave. Gaster longer than broad. Legs long and robust.

Worker minor.—Length, 13-15 mm.

Colour, sculpture and pilosity as in the major.

Head elongate, one-third longer than broad, three times broader in front than behind, the sides feebly convex. Frontal carinae and clypeus as in the major. Eyes large and convex, placed at the posterior third of the sides. Scapes extending beyond the occiput by two thirds of their length. Thorax similar but much more slender. Node two and three quarter times longer than broad, the anterior border convex, the sides parallel; in profile slightly longer than high, the anterior face very short, vertical, the dorsum straight, inclined upward and backward, forming a sharp edge at the junction with the posterior face, the latter feebly convex. Gaster much longer than broad. Legs long and slender.

Female.—Length, 20 mm.

Colour, sculpture and pilosity as in the worker major.

Head very slightly longer than broad, the occipital border and sides straight, or very feebly convex, almost parallel, the occipital angles bluntly rounded. Frontal carinae and clypeus as in the major. Eyes large, rather flat. Ocelli prominent. Scapes extending beyond the occipital border by one fourth of their length. Mesonotum large, flattened on top, parapsidal furrows feebly impressed. Scutellum large, much broader in front than behind, Epinotum short, rounded into the declivity. Node and gaster similar to the major. Legs longer and more slender.

Habitat.—North Queensland: Cape York (W. B. Barnard).

The worker minor corresponds well with the short description given by Forel. The differences in the major and media workers are too great, in my opinion, to regard this as a variety of *subnitidus*. All grades, from the largest to the smallest workers, are found. These represent at least five intermediates, but they differ only in the size of the head. Forel described only the worker minor.

CAMPONOTUS (TANAEMYRMEX) POSTCORNUTUS, n. sp.

(Text-fig. 1, Nos. 7, 8.)

Worker major.—Length, 13-14·5 mm.

Blood red. Gaster black. Mandibles and scapes brown.

Shining. Mandibles coarsely punctate. Head, thorax and node microscopically reticulate, the occipital border smooth and polished. Gaster microscopically striate transversely. The whole body interspersed with fine shallow punctures.

Hair reddish, long and erect, very sparse throughout, except on the apical segments of the gaster. Pubescence very fine and sparse, noticeable only on the antennae and legs. The tibiae, and tarsi have two rows of stout sharp bristles on the under side.

Head large, much broader than long, broadest at the eyes, the occipital border truncate, straight, or very feebly concave, the sides strongly convex, the inferior posterior angles greatly produced backward and slightly outward as short blunt horns. Frontal carinae short, diverging widely behind, there is a well defined longitudinal groove between them extending to the anterior ocellus, where it is deepest. Clypeus broad, convex, feebly carinate, the anterior border produced, straight in the middle; there is a moderately deep fovea on each side near the middle. Eyes large, rather flat, placed at the posterior third of the sides. Ocelli very small, the anterior largest. Scapes extending beyond the occipital border by barely twice their thickness, second and third segments of the funiculus of equal length, longer than the first. Mandibles broad, armed with six large sharp teeth. Thorax one and one third times longer than broad. Pronotum three times broader than long, convex in front and on the sides, the anterior border sharply margined, the margin reflexed, extending to the anterior third of the sides. Mesonotum broader than long, convex above. The metanotum shown as a distinct segment, the sutures rather feeble. Epinotum longer than broad, strongly convex laterally; in profile the dorsum and declivity united in an even arch. The whole thorax is strongly convex longitudinally, the mesonotum sharply marginate below. Node fully twice as broad as long, all four sides convex, the dorsum contracting to a bluntly rounded top edge which is sharply notched in the middle; in profile barely twice as high as long, bluntly pointed above. Gaster longer than broad. Legs robust.

Worker minor.—Length, 8·5-10 mm.

Colour, sculpture and pilosity as in the major.

Head slightly broader than long, broader behind than in front, the inferior posterior angles sharp, not strongly produced as in the major. Clypeus more sharply carinate. Scapes extending beyond the occipital border by half their length. Pronotum and mesonotum similar. Metanotum not defined. Epinotum slender, almost sharp on top. Node thicker, rounded, not notched on top; in profile it is convex above. The rest as in the major.

Habitat.—Western Australia: Bungulla (T. Greaves; J. Clark).

The shape of the head and thorax separate this from all the other Australian species. The major and minor workers are found hunting on the ground and on tree trunks, all day long. They are very active and pugnacious.

CAMPONOTUS (MYRMOSAULUS) VERSICOLOR, n. sp.

Worker major.—Length, 14·8-16 mm.

Length, 14·8-16 mm.

Black. Cheeks, funiculus and first two segments of the gaster blood red. Terminal segments of the tarsi brown.

Subopaque. Mandibles finely and densely striate. Head, thorax and gaster microscopically reticulate and finely punctate.

Hair yellow, very sparse throughout, except on the clypeus and under side of the head, where they are rather long and abundant. Pubescence not apparent.

Head almost one third broader than long, the occipital border concave, the sides strongly convex. Frontal carinae diverging slightly behind, with a sharp longitudinal groove between them, extending to, and including, the anterior ocellus. Clypeus broad and convex, without traces of a carina, the anterior border convex, hardly produced; there is a deep fovea on each side near the middle. Eyes circular; rather flat. The anterior ocellus only present. Scapes extending beyond the occipital border by about twice their thickness; second and third segments of the funiculus of equal length, longer than the first. Mandibles large, armed with six large sharp teeth. Thorax barely twice as long as broad. Pronotum four times broader than long, strongly convex in front and on the sides. Mesonotum circular, the dorsum convex in front, flattened behind, with indications of a longitudinal groove in front. A deep, but not wide, constriction between the mesonotum and epinotum, the latter longer than broad; in profile convex from the anterior border to the bottom of the declivity, without traces of a boundary between them. Node twice as broad as long, all four sides and the dorsum convex; in profile one third higher than long, the dorsum convex. Gaster one fourth longer than broad. Legs long and robust.

Worker minor.—Length, 8·5-10 mm.

Colour and sculpture as in the major. Pubescence much more abundant, very fine and adpressed.

Head longer than broad, the occipital border strongly convex, the sides straight, parallel. Clypeus distinctly carinate. Scapes passing the occipital border by more than half their length. Eyes large and convex. Mandibles with eight to nine large sharp teeth. Thorax similar but much more slender. Node one fourth longer than broad, the anterior and posterior faces straight, the sides convex; in profile as high as long, the anterior

face straight, vertical, the dorsum straight, flat, the posterior face convex, rounded into the dorsum. Legs long and slender. The rest as in the major.

Habitat.—Western Australia: Emu Rocks (H. Reynolds).

This very distinct species is not near any other known to me. A large series of both forms was collected by Mr. Reynolds at Emu Rocks, on the Rabbit-proof Fence, East of Ongerup.

CAMPONOTUS (MYRMOSAULUS) SCUTELLUS, n. sp.

(Text-fig 1, Nos. 9, 10.)

Worker major.—Length, 9·5-11·3 mm.

Brown. Dorsum of pronotum blackish brown. Gaster black.

Opaque. Mandibles coarsely striate-punctate. Head, thorax and node reticulate-punctate. Gaster microscopically reticulate.

Hair reddish, erect, very long and abundant on the thorax and gaster, shorter on the head and legs. Pubescence yellow, very short and sparse throughout.

Head as long as broad, broadest just in front of the eyes, the occipital border concave, the sides strongly convex, the posterior angles rounded. Frontal carinae diverging strongly behind, with a longitudinal groove between them. Clypeus broad and convex, without a carina, the anterior border produced, concave in the middle, with a deep depression at each side near the middle. Eyes large, flat, placed at the posterior third of the sides. Scapes just reach the occipital border; first segment of the funiculus as long as the second, the others subequal to the apical. Mandibles large, triangular, armed with six large, sharp teeth. Thorax one and a half times longer than broad. Pronotum fully twice as broad as long, strongly convex in front and on the sides, subbordered. Mesonotum one third broader than long, convex above. There is a strong constriction between the mesonotum and epinotum, the latter as broad as long, the posterior border straight; in profile much lower than the mesonotum, the dorsum straight, the posterior half submarginate, the declivity vertical, feebly concave near the bottom, longer than the dorsum, submarginate on the sides and above. Node scale-like, almost four times broader than long, the anterior face feebly concave, posterior face and sides convex, the dorsum sharply pointed, convex laterally; in profile somewhat wedge shaped. Gaster much longer than broad. Legs short and robust.

Worker minor.—Length, 5-6 mm.

Colour as in the major. Sculpture coarser, stronger and more densely punctate. Pilosity similar but not so abundant.

Head as long as broad, broadest just in front of the eyes, the occipital border concave, the sides convex. Clypeus carinate, There is a distinct carina between the frontal carinae. Eyes large, globular. Scapes extending beyond the occipital border by barely half their length. Thorax twice as long as broad. The

pronotum not so distinctly subbordered. The constriction between the mesonotum and epinotum strong but not so sharply defined. Epinotum more convex laterally, the posterior border not clearly defined; in profile the declivity vertical, rounded into the dorsum. Node thick, twice as broad as long, the anterior border straight, or feebly concave, the sides, posterior border and dorsum convex; in profile twice as high as long, parallel, the dorsum convex. Legs robust. The rest as in the worker major.

Habitat.—Western Australia: Tammin (J. Clark); Emu Rocks (H. Reynolds); Bungulla (T. Greaves); Merredin (L. J. Newman).

From the description this species is near *C.* (*M.*) *whitei* Wheeler, from Central Australia.

CAMPONOTUS (MYRMOPHYMA) TRISTIS, n. sp.

(Text-fig. 1, Nos. 11, 12.)

Worker major.—Length, 8-9 mm.

Black. Legs brownish black. Apical segments of the gaster very narrowly edged with yellow.

Opaque. Very finely and densely reticulate. Mandibles coarsely striate-punctate.

Hair yellowish, erect, very sparse throughout. Pubescence yellow, fine and adpressed, very sparse throughout.

Head broader than long, broadest at the eyes, the occipital border concave, the sides strongly convex, the posterior angles rounded. Frontal carinae diverging strongly outward behind, with a sharp longitudinal groove between them. Clypeus broad, subcarinate, produced and feebly convex in front; there is a deep depression on each side in front. Eyes large and flat, placed at the posterior third of the sides. The anterior ocellus represented by a large deep puncture, the posterior pair by very feeble punctures. Scapes extending beyond the occipital border by twice their thickness; second and third segments of the funiculus of equal length, one third shorter than the first. Mandibles large, triangular, armed with five to six strong sharp teeth. Thorax one and a half times longer than broad. Pronotum twice as broad as long, strongly convex in front and on the sides, the anterior border margined and slightly raised in front, submarginate on the sides. Mesonotum fully one third broader than long, convex above, submarginate on the sides, much broader in front than behind. Epinotum as long as broad in front, wedge shaped, the posterior ending in a sharp point; in profile the declivity twice as long as the dorsum, straight and vertical, rounded into the dorsum. Node scale-like, the top edge sharp, convex laterally; in profile the anterior face convex, the posterior straight. Gaster longer than broad. Legs robust.

Worker minor.—Length, 5-6 mm.

Colour, sculpture and pilosity similar to the worker.

Head as long as broad, the occipital border straight, the sides convex. Scapes passing the occipital border by almost half their length. Thorax similar to that of the major, but much more slender. The declivity three times as long as the dorsum of the epinotum. Node a little more slender, the top edge, laterally, bluntly rounded. The rest as in the worker major.

Habitat.—Western Australia: Eradu (J. Clark).

Apparently near *C.*(*M.*) *evae* Forel from Queensland.

CALOMYRMEX GLAUERTI, n. sp.

(Text-fig. 1, No. 13.)

Worker.—Length, 9·5-10 mm.

Black, with a faint bronze sheen.

Opaque. Mandibles shining, coarsely striate-punctate on the apical third. Head, thorax and node very densely and finely punctate. Antennae, legs and gaster microscopically punctate.

Hair whitish, erect, long and very abundant, particularly on the antennae, legs and gaster. Pubescence white on the antennae and coxae, golden red on the gaster, where it forms a dense clothing completely hiding the sculpture.

Head very slightly broader than long, broader behind than in front, the occipital border and sides convex, the angles bluntly rounded. Frontal carinae diverging, twice as wide behind as in front. Clypeus convex above, the anterior border straight. Eyes convex, placed at the posterior third of the sides. Scapes of the antennae extending beyond the occipital border by almost half their length; first segment of the funiculus fully one fourth longer than the second, the others subequal. Mandibles armed with five sharp teeth. Thorax fully one and a half times longer than broad. Pronotum two and three quarter times broader than long, flattened laterally, convex and submarginate in front, and on the sides, the anterior angles blunt. Mesonotum much broader than long, transversely oval, submarginate in front and on the sides; in front raised above the level of the pronotum. A strong constriction between the mesonotum and epinotum, the latter truncate and raised higher than the mesonotum in front, longer than broad, flattened laterally; in profile inclined downward behind, the declivity short and indistinct. Node thick, one and a half times broader than long, broader behind than in front, convex laterally above; in profile the anterior face short and vertical, the posterior face feebly convex, twice as high as the anterior face, the dorsum straight, inclined forward. Gaster longer than broad, much broader in front than behind. Legs long and slender.

Habitat.—Western Australia: Murchison River (L. Glauert).

Type in the Western Australian Museum, Perth.

This species is distinct from all the other known forms, and is readily distinguished by its coat of long white hair and the bright golden pubescence on the gaster. The colour is much like that of *C. purpureus* Mayr var. *eremophila* Wheeler, from Central Australia.

Notoncus hickmani, n. sp.
(Text-fig. 1, No. 14.)

Worker.—Length, 4·5-5·3 mm.

Yellowish red. Legs lighter. Gaster blackish brown.

Shining. Mandibles finely striate. Clypeus longitudinally striate in the middle, obliquely so on the sides. The striae are longitudinal between the frontal carinae, curving outward behind and encircling the antennal fovea in front. Behind the eyes the head is smooth and shining, with faint indications of striae. Pronotum irregularly striate-rugose, fine and longitudinal in the centre, coarser and diverging outward behind on the sides. Mesonotum smooth. Epinotum finely and transversely striate behind, the striae diverging obliquely on the sides. Node and gaster smooth.

Hair yellow, erect, rather fine and abundant throughout. Pubescence very fine and sparse, more abundant on the gaster than elsewhere.

Head slightly longer than broad, convex behind and on the sides. Frontal carinae short, almost parallel, very slightly longer than their distance apart. Clypeus broad and convex, projecting and rounded in front. Eyes large and convex, placed behind the centre of the sides. Scapes extending beyond the occipital border by one sixth of their length; first segment of the funiculus twice as long as the second. Mandibles large, armed with eight large sharp teeth. Thorax twice as long as broad. Pronotum twice as broad as long, the dorsum depressed longitudinally in the middle, the anterior angles and sides bluntly raised. Mesonotum rather small, wider in front than behind, strongly convex above. A wide constriction between the mesonotum and epinotum, the spiracles large, placed on the middle of the constriction. Epinotum short, longer than broad; in profile the dorsum straight, the declivity straight and at an obtuse angle, much longer than the dorsum. Node scale-like, fully three times broader than long, the top edge sharp, bluntly pointed laterally; in profile wedge-shaped, bluntly pointed above. Gaster longer than broad. Legs slender.

Female.—Length, 5·5 mm.

Colour and pilosity as in the worker. Sculpture a little coarser. Eyes larger. Ocelli prominent. Pronotum short, feebly shouldered. Mesonotum large, parapsidal furrows deeply impressed. Scutellum large and convex, truncate behind. Epinotal declivity three times longer than the dorsum. Node distinctly concave, or feebly bidentate, above. Wings missing. The rest as in the worker.

Habitat.—Tasmania: Trevallyn (V. V. Hickman).

This species, the first of the genus to be recorded from Tasmania, is dedicated to Mr. Hickman, the Tasmanian Arachnologist, to whom I am indebted for many rare species of ants from that State.

NOTONCUS ROTUNDICEPS, n. sp.

(Text-fig. 1, No. 15.)

Worker.—Length, 3·8-4·5 mm.

Castaneous. Mandibles, clypeus, front of the face, antennae and legs lighter. Head and gaster brown.

Shining. Mandibles finely striate and punctate. Clypeus longitudinally striate in the middle. The striae longitudinal between the frontal carinae, curving outward behind and encircling the antennal fovea as in *N. hickmani.* Head behind the eyes smooth, with some scattered piligerous punctures. Pronotum and mesonotum smooth, with scattered piligerous punctures. Epinotum transversely striate, the striae descending obliquely on the sides. Node and gaster smooth and shining.

Hair yellowish, long and erect, very fine and abundant throughout. Pubescence very fine and sparse, noticeable only on the gaster.

Head very slightly longer than broad, strongly convex behind and on the sides. Frontal carinae parallel, as long as their distance apart in front. Clypeus convex, the anterior border produced, straight in the middle. Eyes convex, placed at the posterior third of the sides. Scapes extending beyond the occipital border by barely one fourth of their length; first segment of the funiculus twice as long as the second. Mandibles armed with five strong sharp teeth. Thorax fully twice as long as broad. Pronotum one and a half times as broad as long, strongly convex in front and on the sides, the dorsum depressed longitudinally in the middle. Mesonotum circular, convex above. The constriction between the mesonotum and epinotum deep and wide, the spiracles placed on top at each side. Epinotum longer than broad, convex laterally; in profile the dorsum feebly convex, the declivity straight, at an obtuse angle, slightly longer than the dorsum, the sides and top subbordered. Node scale-like, barely three times broader than long, convex laterally; in profile three times higher than long, parallel, bluntly pointed above. Gaster much longer than broad. Legs long and slender.

Habitat.—Western Australia: Albany (J. Clark).

Near *N. hickmani*, but smaller and more slender and differently coloured.

STIGMACROS RETICULATA, n. sp.

(Text-fig. 1, No. 16.)

Worker.—Length, 2·2-2·6 mm.

Black. Mandibles, antennae, except the apical segments, tibia and tarsi testaceous. Apical segments of the antennae and the femora brown.

Subopaque. Gaster smooth and shining. Head, thorax and node finely and densely reticulate.

Hair yellow, very short and sparse throughout. Pubescence very fine and adpressed, confined to the antennae and legs.

Head slightly longer than broad, the occipital border straight, the sides convex. Frontal carinae short, flattened, parallel. Clypeus convex above, the anterior border convex and feebly emarginate in the middle. Eyes large, rather flat, placed at the posterior third of the sides. Scapes extending beyond the occipital border by barely one fourth of their length; first segment of the funiculus one third longer than the second. Mandibles armed with five sharp irregular teeth. Thorax one and three quarter times longer than broad. Pronotum twice as broad as long, strongly convex in front and on the sides. Mesonotum longer than broad, broader in front than behind, convex above. Epinotum one third broader than long, the posterior border concave, the angles bluntly produced; in profile the declivity abrupt, feebly concave, longer than the dorsum, the top angles produced, there is a long, sharp spine on each side at the superior third, longer than broad at the base, directed backward and outward. Node scale-like, four times broader than long, convex in front, straight behind, the dorsum bluntly pointed, feebly concave in the middle; in profile four times higher than long, the anterior face convex, the posterior feebly concave. Gaster longer than broad, concave in front below, Legs long and slender.

Female.—Length, 3·3 mm.

Closely resembles the worker, but differs in the following particulars. The whole of the legs and coxae testaceous, the mandibles, antennae and node darker. Eyes larger, more convex. Ocelli large. Mesonotum large, with a distinct longitudinal carina in the middle, parapsidal furrows distinct. Scutellum large, broader in front than behind. Epinotum fully twice as broad as long, the spines much stronger. Node more distinctly notched on top. Wings missing.

Habitat.—Western Australia: Perth (J. Clark).

Near *S. aemula* Forel, but is readily distinguished by its larger size, colour, sculpture and the larger spines on the epinotal declivity.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II, 1930.]

ART. XVI.—*The Structural Features of the Silurian Rocks in the Melbourne District.*

By ANNIE NICHOLLS, B.Sc.
(Howitt Research Scholar in Geology, University of Melbourne).

(With Plates IX., X.)

[Read 12th December, 1929; issued separately 10th March, 1930.]

Introduction.

Early in 1929, it was suggested by Professor Skeats that a detailed map of the folds in the Silurian around Melbourne might prove interesting in view of the fact that the rocks of this district lie in what is usually known as a "crush zone." An attempt has been made to locate the main axial lines, and as many as possible of the minor folds which are so common in the area. The difficulty of the work lay in the complete lack of any kind of outcrop in many of the suburbs, while in others the only exposures of rocks found were small and widely separated road cuttings. On this account there are many gaps in the records of the axial lines, and the positions of some as shown on the accompanying map have been judged largely from better defined folds near them.

Previous Work.

The quarter-sheets of the district (1) compiled by the Geological Survey were of great use since they give the dip and strike of rocks in many places where the rocks are now completely hidden. On the other hand, the Survey had few cuttings to work from, and their dips as judged from surface outcrops alone have not always been found correct.

Dr. N. R. Junner (2) in his work on Diamond Creek has mapped some structural features to the north of the city, and he has located the positions of the Templestowe anticline, Greensborough syncline, and Dry Creek anticline. He discussed the contortion of the western limb of the Templestowe anticline, mainly in connection with the Diamond Creek mine.

Mr. J. T. Jutson (3) while working on the Warrandyte goldfield has mapped the axial lines from the Templestowe anticline to the east. He mentions the crushing of the western limb of the Templestowe fold, but has dealt mainly with the structure of the Warrandyte anticline.

No attempt has been made previously to work out the details of the folding in the districts near Melbourne.

General Structure.

The Silurian rocks of the area are interbedded mudstones, sandstones, and shales, often with iron oxide deposited along the

bedding. The beds vary in colour and texture, but it is impossible to pick out characteristic bands by which amount of folding or faulting might be judged. The rocks have been compressed into folds whose axes run fairly parallel in the Melbourne area. The strike of these axes varies from N.20-25°E. to N.35°E. in the southern part of the area.

In the eastern suburbs from Box Hill to Oakleigh the folds persist over the whole length of the area studied, and show a considerable thickness of rocks in their limbs. Towards the city, however, the major axes appear to lie much closer together, although they still persist over long distances. The dips of the rocks in the two limbs vary, but it has been found that from the Blackburn fold to the City the western limbs of the main anticlines show the steeper dip, giving a list of the axial plane to the east. Jutson states that at Warrandyte, the axial plane of the main anticline lists to the west. He has found that five normal folds which occur further south have been compressed at Warrandyte into one great arch with minor puckers on its crest. The Warrandyte zone is therefore one of intense compression, and its features do not resemble those of the city area.

Apparently the compression increases from the Blackburn anticline westward to the City, since the folds lie closer together there. This is shown also by the presence of numerous minor folds with axes parallel to the major lines. These minor folds show relatively small thicknesses of rocks in their limbs, and are usually pitching strongly, accounting for the fact that they are not persistent along the length of the fold. They are generally local puckers consisting of an anticline and syncline close together, although separated by a much greater distance from the next pucker.

It has always been assumed that the small folds occur on the crests of the main anticlines. While this appears to be the case at Warrandyte, the writer has found that the minor folds in the Melbourne area occur not at the crests of the anticlines, but along their western limbs. Evidently in such a series of folds as occur here, the rocks of the steeper dipping limb are subjected to greater compression than the rocks of the opposite limb. The type of structure is shown in Section A, Text-fig. 1. A similar structure is figured by Hobbs in "Earth Evolution and its Facial Expression," but he gives it merely as a typical geological section, and does not discuss the characters of the folds.

Reversed faulting is very common in the zones of intense folding, but the faults have generally an unusually small angle of hade and do not seem to have affected the positions of the axial lines to any great extent. The faults show strikes closely parallel to the strike of the beds, but no attempt has been made to map them since in the absence of characteristic beds it is impossible to judge the displacements they have caused. The basic dykes so common in the area frequently occur along these fault planes.

Associated with some of the crushed areas, small quartz veins have been found. They form a network suggesting the passage of solutions along fine crevices in the shattered rock, and no veins of any great size have been found. Since the crush zones represent areas of intense local compression, it would not be expected that any large quartz veins would be found such as occur in the zones of tensional stress at the axes of the anticlines.

Details of Folds.

The Blackburn anticline, Bulleen syncline, and Templestowe anticline named by Jutson persist further south than his map shows them, the first two being traced to Oakleigh and the last to Tooronga. Very little work has been done as far east as the Blackburn fold, but on the western limb of the Templestowe anticline puckers occur, well shown in a brick pit near Camberwell Road. Both Junner and Jutson mention the contortion of the western limb of this fold. Each of the succeeding anticlines traced has been found to show the same folding of the western limb at some place along its length. With most of the folds the structure is not very complicated, being in the form of one or two small puckers only. With at least one anticline, however, the one which passes through Studley Park, the rocks have been crushed into numerous small folds, and are greatly contorted and faulted. The most southerly outcrop of this crush zone is indicated by the dips on the south bank of the Yarra east of Princes Bridge, as shown on Quarter Sheet No. 1, S.E. Further north in Studley Park excellent sections of crushed rocks are to be found. To the north of this, the anticline is covered by the Darebin Creek basalt, suggesting that the pre-basaltic stream found the crushed rocks a line of weakness along which it carved its valley.

The road down to Johnston Street Bridge shows two minor puckers pitching strongly south. Between the lower of these and the next syncline occurs a shattered area shown in Section B, Text-fig. 1, where the folds are sometimes only a few feet apart and where reversed faulting is very common. At Dight's Falls there occurs a distinctive thickly bedded sandstone which appears to dip north-east. It seems probable that this sandstone band may be correlated with a well marked syncline which occurs just across the neck of the meander, and that its apparent dip

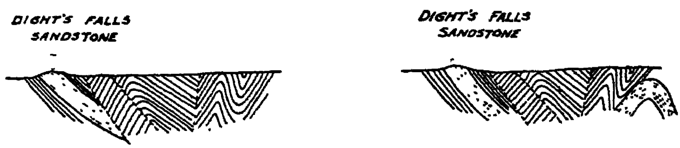

FIG. 2—Possible types of structure in the Studley Park crush zone.

north-east is due to a strong northerly pitch. The fact that the westerly dipping arm does not appear may be due to the complicated faulting of the rocks to the east having the total effect of a reversed fault hading east, in which case the sandstone would have been lost by erosion; or the folding may have been such that the sandstone remained below the surface to the east. (Fig. 2.) In either case it seems likely that the extreme contortion of the rocks to the east is due to their having been thrust in some way against the resistant sandstone. On account of the northerly pitch of this bed, it does not outcrop to the north, and to the north the shattered zone also is absent, the rocks along the river bank south of Alphington having a uniform westerly dip.

The local crushed areas occur in many other places near the City, at Church Street Bridge, Heyington cutting, Jolimont cutting, and in other parts. In the Victoria Bridge road cutting an excellent outcrop of an anticline occurs. This shows a greater thickness of rocks in the eastern limb than is usual with a minor fold, yet it is about ten chains west of the major axial line as judged from outcrops to the north and south. No other outcrops could be found in the district, so it is impossible to judge whether the anticline represents a minor pucker larger than usual, or whether the major axis has been displaced by faulting. The area is one in which several reversed faults occur, some with quite a large angle of hade. The strong southerly pitch and the almost north to south strike of the axis are usual features of minor folds, but both might have been caused by faulting.

In his paper on Diamond Creek, Junner speaks of a sharp anticlinal axis at Dry Creek, north of Greensborough. He states that the axial plane lists to the east at 70°, and continues: " Going further east from here along the E-W bend of the Plenty R., several small anticlines and synclines occur close together." This is obviously a slip, since the E-W bend of the Plenty lies to the west of Dry Creek. The writer has located these small folds, and they occur down the western limb of the Dry Creek anticline.

Summary and Conclusion.

Mapping of the available outcrops of the Silurian rocks in the eastern suburbs of Melbourne has shown the axes of the folds to run fairly parallel across the area, striking approximately N.25°E. The axes of the major folds lie closer together as the City is approached, and greater compression is shown also by the numerous minor puckers and small crush zones which appear. These outcrop down the western limb of the anticlines, and this limb has been found to show the greater dip, indicating that greater compression acts on the steeper dipping limb. Small quartz veins are associated with the crush zones, but large reefs are confined to the axes of the anticlines. The details of the more important folds in the area have been discussed.

In conclusion, I would like to express my gratitude to Dr. Summers for his unceasing interest and assistance throughout the year. I would also like to thank Mr. J. S. Mann for his help in the preparation of my map and sections.

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Description of Plates.

Plate IX.

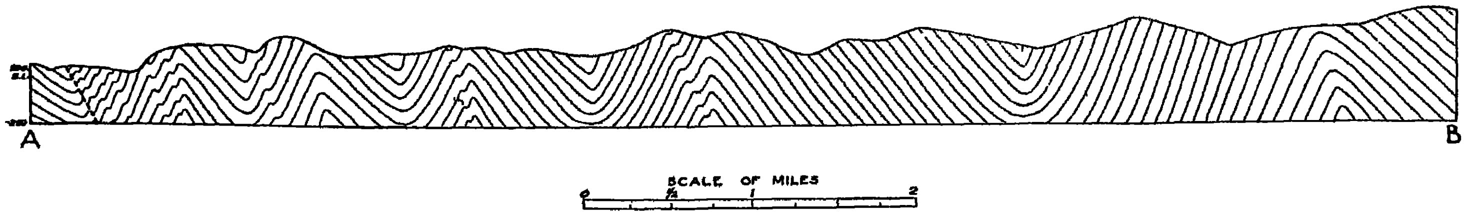
Structural map of the area studied showing major axial lines. The dips in the crushed zones have not been marked in. C.Z.—Studley Park crush zone shown in Text-fig. 1. Section B. V.—Victoria Bridge anticline.

Plate X.

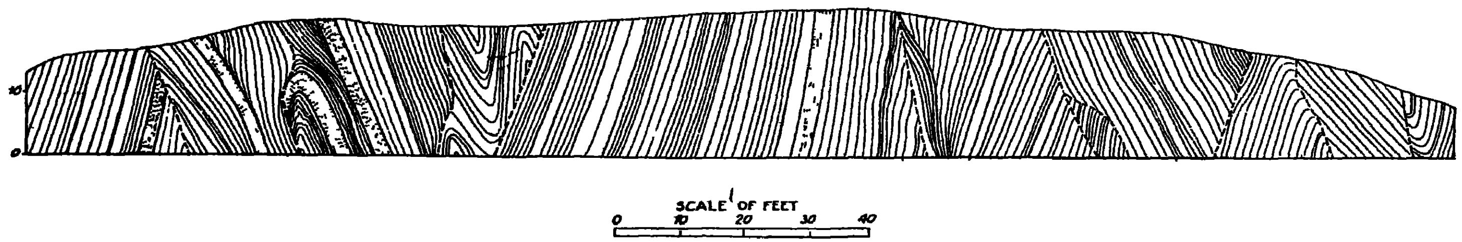
Photographs of rocks in Studley Park crush zone, on road cutting from Johnston Street Bridge to Dight's Falls.

Fig. 1.—An incompetent shale crumpled under a resistant sandstone.

Fig. 2.—An anticline and syncline crushed close together, and faulted along their axes.

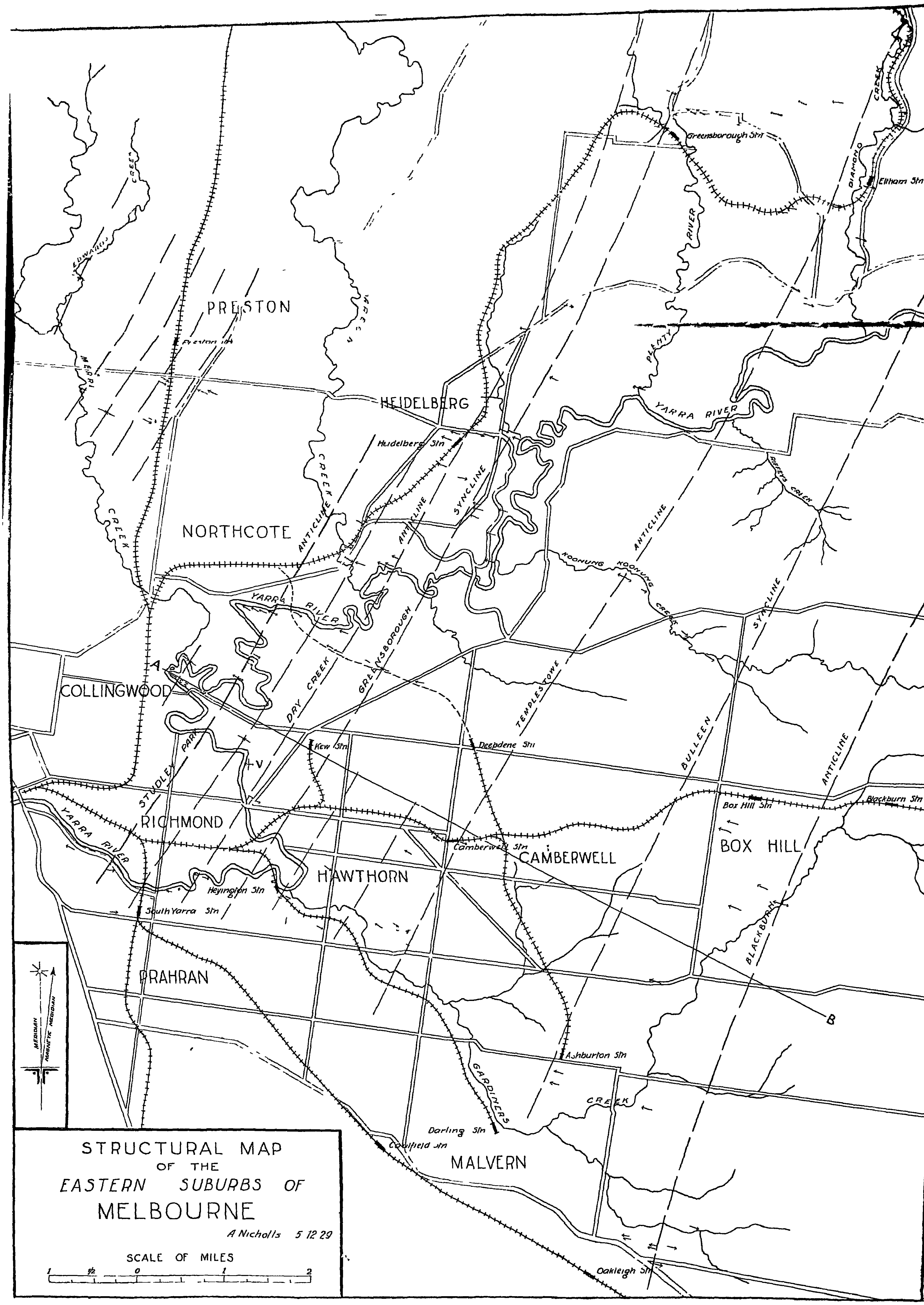


SECTION A —Section line AB on map, Plate IX To show relief the vertical scale was exaggerated, but since the width of the beds are conventional only, the dips of the beds have not been altered to correspond



SECTION B —Sketch section of cutting from Johnston Street Bridge to Dight's falls, vertical and horizontal scales the same Dotted beds represent resistant sandstones against which shales have been crushed

FIG 1



STRUCTURAL MAP
OF THE
EASTERN SUBURBS OF
MELBOURNE

A Nicholls 5 12 29

SCALE OF MILES
1 ½ 0 1 2

Fig. 1.

J. S. Mann photo.

Fig. 2.

Folding in Silurian Rocks. Studley Park, Victoria.

caris or *Ceratiocaris* (4, 5). *Ceratiocaris*, however, is solely a Silurian genus, and furthermore the specimen is clearly more allied to *Hymenocaris* Salter. *Hymenocaris* is a common Upper Cambrian genus in Wales (5), and also frequent in the Middle Cambrian of North America (6). The carapace in this genus is univalved, but folded along the dorsal line into two equal flaps. The remarkable ornament on the carapace of the Victorian species has not hitherto been recorded, and it has suggested the specific name, *ornata*.

Order PHYLLOCARIDA Packard.

Sub-order HYMENOCARINA Clarke.

Family HYMENOCARIDAE Salter.

Genus **Hymenocaris** Salter, 1853.

HYMENOCARIS ORNATA, sp. nov.

(Plate XI., Figs. 1-3.)

Description.—Carapace thin, almost membranous, preserved as impression and counterpart. Its shape is semi-oval, more pointed at anterior margin than posterior; both ends are truncate, the valve is narrower at the anterior end than the posterior, and it shows an umbo. The ventral margin is gently convex. The greatest length is 22 mm. (20 mm. without appendages). The entire width is 11 mm. (9 mm. without appendages).

The ornament consists of very delicate, fine white lines, with saw-tooth-like shining scales, packed very closely, crossing specimen from dorsal to ventral margin, with a strong tilt towards the posterior just before reaching the ventral margin.

The scales on the lines are each about $\frac{1}{2}$ mm. in length, and in shape like the thecae of a graptolite, with a long gradual concave curve towards the dorsal margin, meeting a short sharp concave curve towards the ventral margin at almost a right angle, which points to the posterior (Pl. XI., Fig. 3). The lines of scales are each about $\frac{1}{2}$ mm. apart. Many of the white scales are overlain by a thin shining skin.

The same saw-tooth-like markings are seen on body segments, but not on the carapace, in some species of *Ceratiocaris* figured by Jones and Woodward (5, pls. vi., xi.). They are described as "lattice ornament."

Protruding Appendages.—(*a*) Rostrum.—Horizontal, protruding from anterior near dorsal margin, 3 mm. long.

(*b*) Stalked eye (?).—This feature is recorded for *Hymenocaris perfecta* by Walcott (6, pp. 159 and 183), but not illustrated. It is a broad leaf-shaped appendage, 4 mm. long and 1·5 mm.

broad, projecting diagonally upwards from the anterior near the ventral margin.

(*c*). Three jointed cephalic appendages.—One of them (3·5 mm. in length) projects from the anterior margin immediately below the stalked eye (?), and is possibly the antennule. Two are longer (up to 12 mm.), and folded back parallel to the ventral edge, and are possibly antennae.

(*d*) Cercopods.—Projecting from the posterior margin are two flattened leaf-like appendages which suggest cercopods attached to abdominal segments hidden beneath the carapace. They have the shape characteristic of cercopods seen in illustrations of *Hymenocaris perfecta* (6). They are subtriangular with the base attached beneath the valve and one cercopod has a pair of outer spines or setae. The cercopods are 3 mm. in length and 4 mm. in width.

(*e*) Uropods.—On the ventral margin near the posterior are two flattened appendages 2 mms. long and about 1 mm. broad, which may be the abdominal appendages (uropods).

Holotype (Reg. No. 993) and counterpart (Reg. No. 994) in the collection of the Department of Geology, University of Melbourne.

The second specimen to be described from the same quarry shows an impression of a valve, evidently a brachiopod, and also numerous specimens of *Bryograptus victoriae* T. S. Hall.

Only one brachiopod impression was found, but since hitherto none has been recorded from the Lancefield zone of the Lower Ordovician, this find is interesting, as it adds to the type fauna.

The fossil is an impression of the dorsal valve, It is evidently somewhat compressed and distorted owing to its preservation in highly folded slates, since a small portion of the ventral valve has been revealed beneath the dorsal valve by the pushing over of the latter, while from the same cause the hinge line is longer on the right side of the umbo than on the left.

Mr. Frederick Chapman has examined the valve and compares it with *Siphonotreta* de Verneuil.

Class BRACHIOPODA.

Family SIPHONOTRETIDAE Kutorga.

Genus cf. **Siphonotreta** de Verneuil, 1845.

? Siphonotreta lancefieldensis, sp. nov.

(Plate XI., Fig. 4.)

Description.—The fossil is a thin, white external impression of the dorsal valve with portion of the other valve protruding from

beneath. It is semi-oval in outline, with an almost straight hinge-line, whose length is nearly equal to the entire breadth of the shell. The umbo is small and obtuse. The valve measures 9 mm. in breadth and about 6 mm in length. The thin, white oval impression is ornamented with a large number of fine, white equidistant concentric growth lines packed closely. In addition, radiating ridges branch out from the small umbo. These radiating ribs are most marked near the anterior margin. A question arises, are some of the larger of them cracks caused in the fossil shell by the pressure of overlying beds? The valve is freely ornamented with small circular pits which suggest the former presence of spines. They are more numerous near the margin of the shell than near the hinge, but their disposition is irregular.

Holotype in the collection of the Department of Geology, University of Melbourne (Reg. No. 995).

In many ways (?) *Siphonotreta lancefieldensis*, sp. nov., may be compared with (?) *Siphonotreta minnesotensis* from the Trenton limestone of Minneapolis, Minnesota, described and figured by Hall and Clarke (7, p. 177, pl. iv., figs. 37, 38).

The writer wishes to thank Mr. Frederick Chapman for invaluable help and advice with these notes; also Professor L. A. Cotton, of the University of Sydney, who granted her facilities for the work; and Mr. W. S. Dun, Palaeontologist to the Geological Survey of New South Wales, who made available various books of reference.

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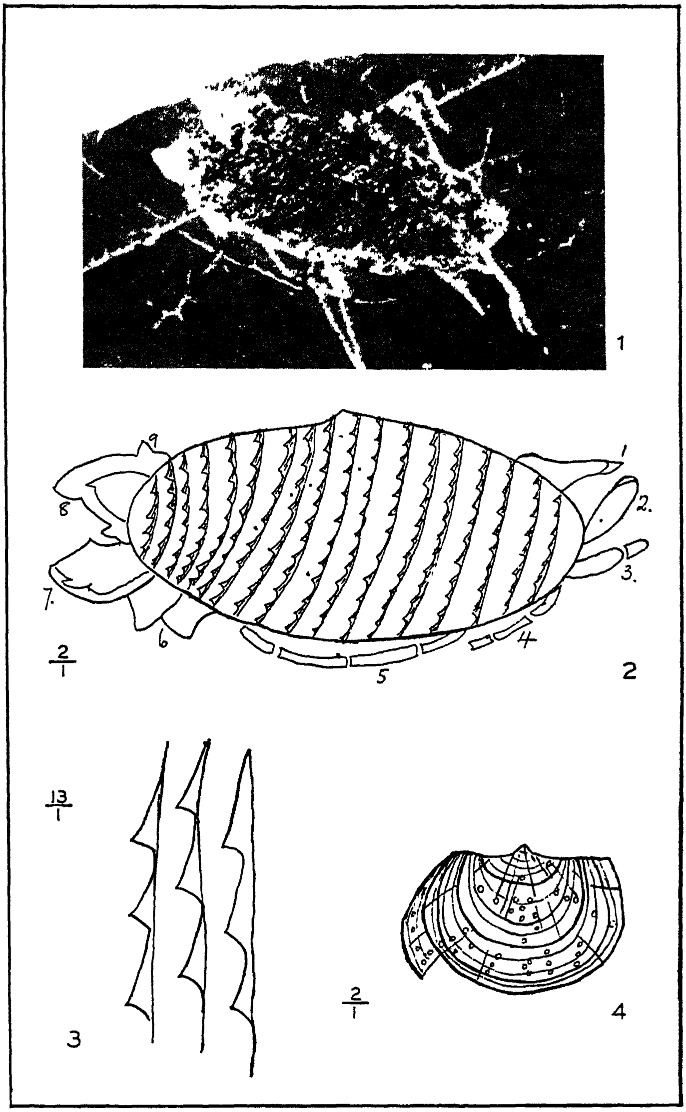
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Explanation of Plate XI.

Fig. 1.—*Hymenocaris ornata,* sp. nov. Lower Ordovician (Lancefield zone), Lancefield, Victoria. Holotype. Melb. Univ. Geol. Dept. Reg. No. 993.

Fig. 2.—*H. ornata,* sp. nov. 1, Rostrum. 2, Stalked eye (?). 3, 4, 5, Cephalic appendages. 6, Uropods. 7, 8, Cercopods. 9, Setæ.

Fig. 3.—*H. ornata,* sp. nov. Enlarged diagram of ornament.

Fig. 4.—(?) *Siphonotreta lancefieldensis,* sp. nov. Dorsal valve and portion of ventral valve, slightly distorted by compression.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II., 1930.]

ART. XVIII.—*The Influence of the type of thickening on the rate of flow in models of Wood Vessels.*

By B. J. GRIEVE, B.Sc.

(Howitt and National Rose Society Scholar, Botanical Department, University of Melbourne).

(With Plate XII).

[Read 12th December, 1929; issued separately 13th March, 1930.]

Introduction.

It is a well known fact that, in the conducting vessels of plants, various types of thickenings are present on the inner walls, and interest has centred in their function. These thickenings in the form of annuli, spirals, and networks, are of such a nature that they are preëminently suited to resist crushing forces (1).

They occur on the inner walls of the vessels through which the sap flows, and it is to be expected that they would exert some influence on the rate of flow of the sap, i.e., they would produce friction and introduce turbulent motion into the upward stream when it had sufficient velocity. Professor Ewart (2) has found that, owing to the presence of these thickenings and to the transverse walls, the flow of water through the capillary tubes of plants (viz., tracheae) is only about half what might be expected as calculated by Poiseuille's formula.

It was then thought that the different types of thickenings in the vessels might affect the rate of flow of the sap differently.

To test whether such different thickenings might have some relative effect on the rate of flow, the following experiments were carried out, using a model. This model was made to represent as closely as possible a wood vessel, magnified equally in all directions, but for practical reasons with the thickenings on a rod inside an outer tube, instead of on the inner surface as in a wood vessel.

The Apparatus.

Inside a glass tube (A) with an internal diameter of 2·3 cm. and 91 cm. in length, was fitted a solid glass rod (B) 1·9 cm. in diameter and 106 cm. in length. The glass rod was arranged so that it projected about 7·5 cm. at each end. After centring, the glass rod was fixed firmly in position, using wooden plugs,

and the position of the plugs was scratched on the outer glass tube, so that they could always be placed in the same position on re-assembling the apparatus.

A rubber tube (C) was next fitted over one end of the outer glass tube, this being connected up with an aspirator (D) as shown in Figure 1.

On the other end of the glass tube another similar rubber tube with a glass tap was fitted. The positions where the rubber tubes fitted on were noted.

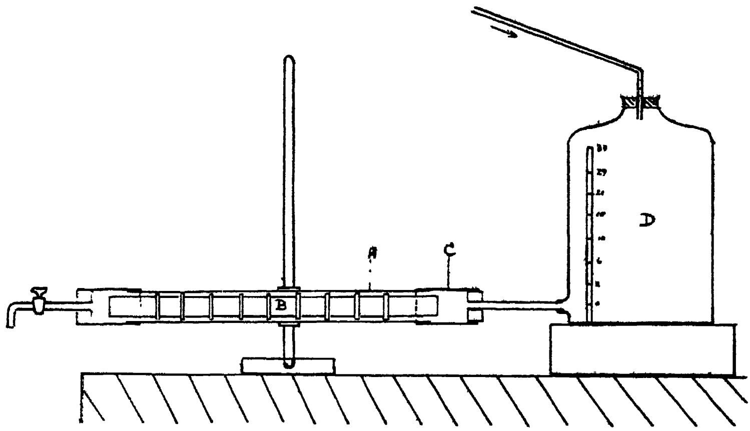


FIG. 1.—Diagram showing the arrangement of the apparatus.

The apparatus was then clamped in a horizontal position, so that every part of it was 6 inches above the level of the bench.

A second aspirator with a regulating tap was situated at 2 ft. 6 in. above the level of the bench. Water from this could be run into the first aspirator in order to maintain a constant level in the water there.

Method of Procedure.

In all the following experiments a stop watch was used to determine the time of flow of water through the tube, 60 seconds being the time in all cases. The temperature of the water flowing through the apparatus was taken at the beginning and end of a set of experiments, in order to correct for viscosity effects.

In most of the experiments difficulty was experienced in getting all the air out of the apparatus, i.e., from between the inner and outer tubes. This difficulty was overcome by first running methylated spirits rapidly through the apparatus and, following this by hot boiled water, passed through at a much slower rate. The remainder of the air left after running the

alcohol through was dissolved out by the heated boiled water.

The velocity at which the water could be run through the apparatus was arranged for by using a series of "heads" of water in the first aspirator, viz., from a head of 33 cm. to a head of 1·2 cm., with 5 cm. and 2 cm. differences in level.

The volumes of water flowing through the apparatus in any set of experiments were measured in a large measuring jar.

Method of arranging the thickenings.

In the first attempts paraffin was used to introduce different types of thickening on to the inner tube. It was found impossible, however, to obtain a smooth surface on the paraffin, and consequently this method was abandoned.

Rubber banding of a size 1 mm. square in cross section was adopted for use for the spiral and annular types of thickening. The distance between the inner rod and the outer tube was 1·5 mm. on any particular side. When the rubber band was wound on, a space of 0·5 mm. was therefore left between the rubber band and the outer tube. The elastic band was fixed in position at each end by means of thin rubber bands. A specially made length of rubber tubing 1 mm. thick was used for the pitted and reticulate thickenings.

The type and arrangement of the thickenings as found in the vessels of the Cucumber stem served as a model on which the thickenings used in the experiment were based.

Camera lucida drawings were made of vessels showing different types of thickenings on their walls, and the distances apart of the thickenings in relation to the width of the vessel were measured, using a prepared scale. The ratio found was applied in working out distances between turns of the spiral, or the rings, in the model.

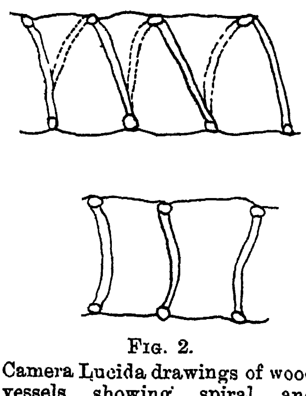


FIG. 2.
Camera Lucida drawings of wood vessels showing spiral and annular thickenings.—From a Cucumber stem.

In the case of the pitted and reticulate type of thickening, the procedure was adopted of working from rows of regularly arranged circular pits, through elongations of these to a reticulate condition. The different types of thickening used in each experiment are illustrated in Plate XII.

Experiment 1.—With no thickenings on the inner glass rod. Water was run through the apparatus for some time after all the air had been removed. Using the procedure above described, the results set out in the following table were obtained:—

Temp of Water		Head of Water Cms		Inches		Vol. in cc. per sec.		Linear Rate of Flow cms per sec.
15°C	-	33·00	-	13	-	29·10	-	22·00
	-	27·94	-	11	-	26·10	-	19·80
	-	22·86	-	9	-	24·30	-	18·26
	-	17·78	-	7	-	21·90	-	16·50
	-	15·24	-	6	-	19·60	-	14·84
	-	10·16	-	4	-	15·53	-	11·90
	-	7·62	-	3	-	13·93	-	10·40
	-	5·08	-	2	-	11·70	-	8·80
	-	2·54	-	1	-	9·10	-	6·80
	-	1·27	-	½	-	7·68	-	5·80

Estimation of the Linear Rate of Flow.—The volume of water contained in the cylindrical space between the rod (19 mm. diam.) and the tube (23 mm. diam.) in length of 55 cm. is 72 cc.

Volume of water flowing through in 1 second at 1·27 cm. head, 7·68 cc.

In 9·37 seconds 72 cc. will move a distance of 55 cm. Hence Linear Rate of Flow equals 5·8 cm. per second at a head of 1·27 cm. Linear Rate of Flow at other heads:

$$\frac{\text{Vol. of flow in 1 sec. at 1·27 cm. head}}{\text{Vol. of flow in 1 sec. at new head}} \times \frac{5·8}{1}$$

Experiment 2.—With spiral thickenings (Plate XII., Fig. 1). A rubber band 1 sq. mm. in cross section and 9 feet in length was wound on the inner glass rod, the turns of the spiral being placed 1·1 cm. apart and giving 46 turns over a length of 55 cm. This arrangement of the spiral was, as indicated earlier, modelled on a simple protoxylem type of spiral in a longitudinal section of a Cucumber stem. The diameter of the vessel was measured to the insides of the spiral thickenings, since this is the condition under which the present experiment is being conducted, i.e., the thickenings on the outside of a glass rod.

Diameter of vessel in Cucumber stem, 25 mm. Average distance apart of the turns of the spiral, 18 mm. Average width of band, 2 mm. Ratio of distance apart of the bands to the diameter of the vessel, 18:25.

Therefore spiral thickenings on the model should be set 1·36 cm. apart.

In the actual experiment the spiral was wound at distances of 1·1 cm. apart (46 turns), i.e., somewhat more closely spaced than is the case in the Cucumber vessel. The rod, bearing the bands in position, was then carefully placed inside the outer tube, centred and fixed there, using the wooden plugs. The apparatus was then connected up as described earlier.

After elimination of the air the following readings were made:—

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	21·23	17·08
	27·94	18·90	15·30
	22·86	16·86	13·57
	17·78	14·75	11·87
	15·24	13·86	11·10
	10·16	11·43	9·18
	7·62	10·15	8·17
	5·08	8 30	6·78
	2·54	6·30	5·10
	1·27	5·30	4·27

Linear Rate of Flow.—Volume of rubber thickenings, 2·74 cc. Volume of water contained in a length of 55 cm., 69·26 cc. Linear rate of flow at 1·25 cm. head, 4·27 cm. per sec.

Experiment 3.—With an increased number of spiral thickenings. The number of spiral turns was increased to 114 in this

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	18·20	15·10
	27·94	16·50	13·60
	22·86	14·46	12·00
	17·78	12·70	10·60
	15·24	11·60	9·70
	10·16	8·50	7·00
	7·62	7·13	5·90
	5·08	5·80	4·20
	2·54	3·75	3·10
	1·27	3·35	2·80

experiment, and they were wound on at distances of 4 mm. apart. This was modelled on an older vessel in the Cucumber stem which was showing a more closely wound spiral.

Volume of rubber thickenings, 6·8 c.c.

Experiment 4.—With spiral thickenings doubly wound. A double wound spiral, such as is found occurring in the larger

Temp. of Water		Head of Water in cms.		Vol. in cc. per sec.		Linear Rate of Flow cms per sec.
15°C	-	33·00	-	19·30	-	16·00
	-	27·94	-	18·00	-	14·90
	-	22·86	-	16·10	-	13·30
	-	17·78	-	14·20	-	11·76
	-	15·24	-	12·90	-	10·70
	-	10·16	-	9·97	-	8·26
	-	7·62	-	8·43	-	7·00
	-	5·08	-	6·90	-	5·70
	-	2·54	-	5·13	-	4·25
	-	1·27	-	4·10	-	3·40

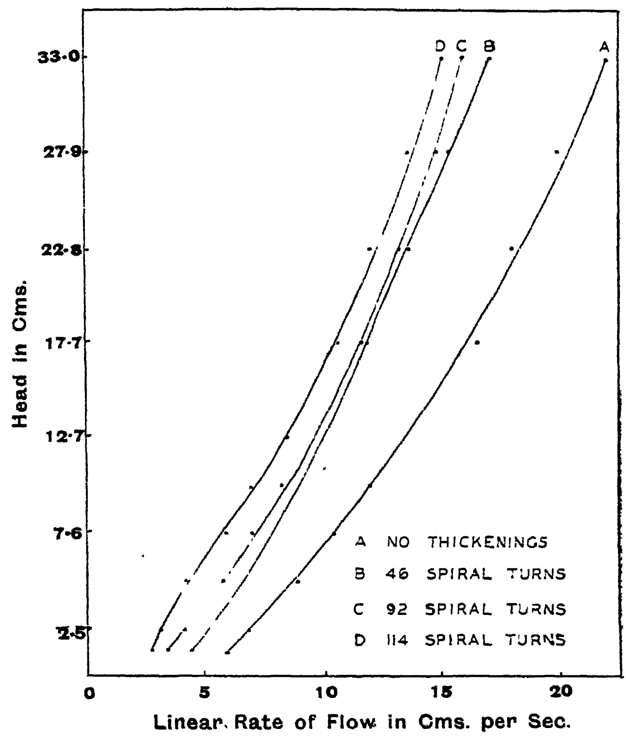


FIG. 3.—The effect of Spiral thickenings on the rate of flow.

vessels of the xylem in the Cucumber stem, was used in this experiment. Two separate spirals of 46 turns each were wound on so that the distance between any two turns of the spirals was 4·7 mm. The spacing here approximates very closely to that found in the Cucumber vessels. The volume of the rubber thickenings was 5·48 cc.

Experiment 5.—With annular thickenings (Plate XII., Fig. 2). The 9 feet of rubber band used in a previous experiment (46 spirals) was cut up and made into 35 rings of a size large enough to make a tight fit on the inner glass rod, and these were spread over 55 cm. at distances of 1·5 cm. The spacing here approximated very closely to the relative spacing of the annular thickenings in the Cucumber vessel. Volume of rubber rings, 2·74 cc.

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	17·20	13·66
	27·94	15·55	12·35
	22·86	14·40	11·43
	17·78	12·70	10·09
	15·24	11·78	9·34
	10·16	9·90	7·85
	7·62	8·75	6·94
	5·08	7·13	5·66
	2·54	5·33	4·21
	1·27	4·45	3·54

Experiment 6.—With increased number of annular thickenings. These were increased to 46, so as to be equal in number to the turns of the spiral in Experiment 2. These 46 rings were spaced at distances of 1 cm. apart. Volume of rubber rings 3·59 cc.

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	15·40	12·37
	27·94	14·05	11·30
	22·86	12·78	10·27
	17·78	11·22	9·01
	15·24	10·45	8·41
	10·16	8·45	6·78
	7·62	7·46	6·00
	5·08	6·20	5·00
	2·54	4·72	3·90
	1·27	3·90	3·14

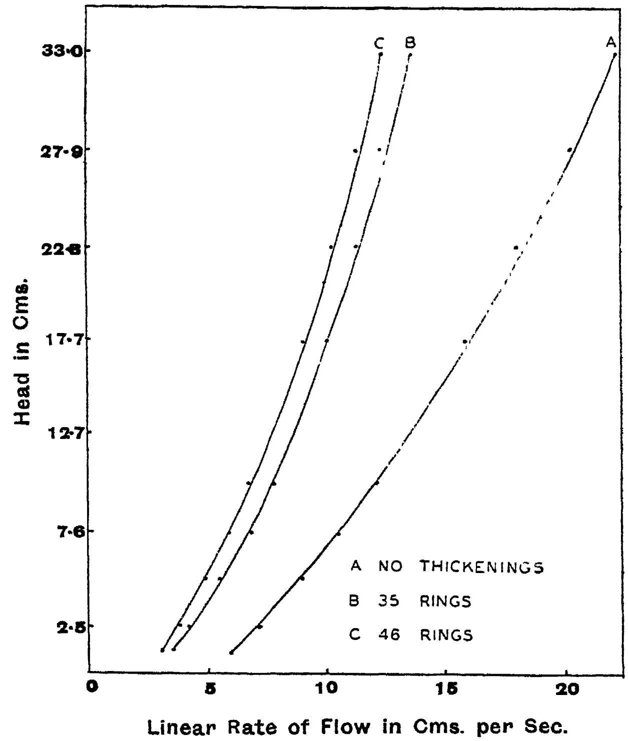


FIG 4.—The effect of Annular thickenings on the rate of flow.

Experiment 7.—With solid rubber tube (Plate XII., Fig. 3). In this experiment a solid rubber tube 1 mm. thick and 55 cm. long was fitted on to the inner glass rod. Volume of rubber thickening, 39 cc.

Temp. of Water		Head of Water in cms.		Vol. in cc. per sec.		Linear Rate of Flow cms per sec.
15°C	-	33·00	-	15·78	-	26·33
	-	27·94	-	14·23	-	23·77
	-	22·86	-	12·50	-	20·87
	-	17·78	-	10·45	-	17·46
	-	15·24	-	9·45	-	15·76
	-	10·16	-	6·91	-	11·54
	-	7·62	-	5·75	-	9·60
	-	5·08	-	4·37	-	7·28
	-	2·54	-	3·23	-	5·37
	-	1·27	-	2·55	-	4·26

Experiment 8.—With rubber tube pitted (Plate XII., Fig. 4). Circular pieces of rubber 3 mm. in diameter were cut out of the solid rubber tube, giving a pitted appearance when placed on the glass rod. The pits were arranged in five rows of 18 each, spread over the length of 55 cm. The volume of the rubber thickening was now 38·37 cc.

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	13·07	21·50
	27·94	11·60	19·06
	22·86	10·10	16 59
	17·78	8·66	14·23
	15·24	7·80	12·80
	10·16	5·90	9·70
	7·62	4·93	8·08
	5·08	3·81	6·26
	2·54	2·50	4·10
	1·27	1·85	3·04

Experiment 9.—With double number of pits in rubber tube (Plate XII., Fig. 5). The number of pits cut in the solid rubber were doubled for this experiment, and were made to alternate in position with the other 90 pits. The volume of the rubber thickenings was 37·74 cc.

Temp. of Water	Head of Water in cms.	Vol. in cc. per sec.	Linear Rate of Flow cms. per sec.
15°C	33·00	11·98	19·17
	27·94	10·55	16·86
	22·86	9·03	14·43
	17·78	7·63	12·20
	15·24	6·73	10·76
	10·16	5·05	8·08
	7·62	4·00	6·40
	5·08	3·00	4·78
	2·54	2·07	3·30
	1·27	1·55	2·48

Experiment 10.—With round and elongated pits in rubber tube (Plate XII., Fig. 6). A number of the pits (104) in the rubber were enlarged to form an elliptic area, while the other pits (74) were left as before. The volume of the rubber thickening was 34·38 cc.

Temp. of Water		Head of Water in cms.		Vol. in cc per sec.		Linear Rate of Flow cms. per sec.
15°C	-	33·00	-	12·98	-	19·00
	-	27·94	-	11·50	-	16·83
	-	22·86	-	10·13	-	14·82
	-	17·78	-	8·75	-	12·80
	-	15·24	-	8·13	-	11·88
	-	10 16	-	6·10	-	8·94
	-	7·62	-	5·05	-	7·38
	-	5·08	-	3·70	-	5·40
	-	2·54	-	2·43	-	3·54
	-	1·27	-	2·05	-	3·00

Experiment 11.—With elongated pits in rubber tube (Plate XII., Fig. 7). All the pits in the rubber tube were cut to an elliptic shape, giving a thickening approaching to a reticulate type. Volume of rubber thickening, 30·43 cc.

Temp. of Water		Head of Water in cms		Vol. in cc. per sec.		Linear Rate of Flow cms per sec.
15°C	-	33·00	-	13·81	-	18·22
	-	27·94	-	12·20	-	16·11
	-	22·86	-	10·61	-	14·00
	-	17·78	-	8·95	-	11·83
	-	15·24	-	8·05	-	10·63
	-	10·16	-	6·00	-	7·90
	-	7·62	-	4·75	-	6·25
	-	5·08	-	3·75	-	4·96
	-	2·54	-	2·83	-	3·73
	-	1·27	-	2·21	-	2·92

Experiment 12.—With reticulate thickening (Plate XII., Fig. 8). The rubber tube on the glass rod was further cut away for this experiment, so the thickenings left were of a pronounced reticulate character. Volume of rubber thickening, 19 cc.

Temp. of Water		Head of Water in cms.		Vol. in cc. per sec.		Linear Rate of Flow cms. per sec.
15°C	-	33·00	-	13·45	-	14·03
	-	27·94	-	12·03	-	12·55
	-	22·86	-	10·11	-	10·57
	-	17·78	-	8·70	-	9·07
	-	15·24	-	7·83	-	8·18
	-	10·16	-	6·13	-	6·40
	-	7·62	-	5·06	-	5·28
	-	5·08	-	4·05	-	4·23
	-	2·54	-	2·85	-	2·96
	-	1·27	-	2·25	-	2·35

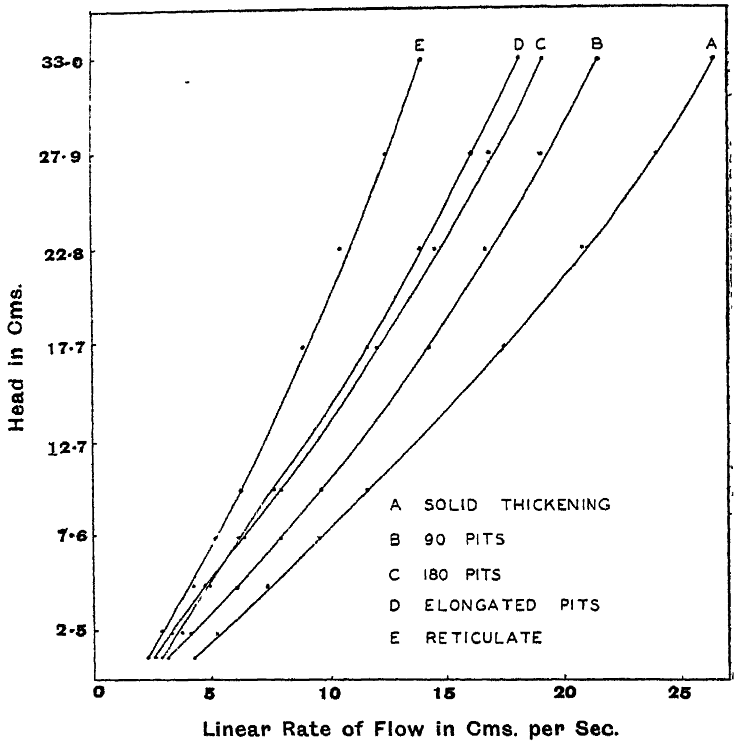


Fig. 5.—The effect of Pitted and Reticulate thickenings on the rate of flow.

Discussion of Results.

An examination of the graphs plotted from the results of Experiments 1, 2, and 3 shows that the introduction of spiral threads into a cylindrical channel has a marked effect on the rate of flow of water through such a space, but this retardation is still more marked when a corresponding number of annular rings are introduced (See Fig. 6). This difference, particularly with high rates of flow, can be attributed to eddy currents forming at each ring, whereas with a spiral thread the flow tends to follow a spiral path. The spiral thread increases the distance the liquid must travel in order to pass through the tube, but the resistance to flow is not increased to the same extent as with the formation of eddy currents. The greater the number of annular rings the greater is the resistance to flow, but the proportional increases decrease as the total number of rings increases.

Two parallel spiral threads increase the resistance to flow only to a slight extent as compared to a single spiral thread,

since there are merely two spiral channels of water current instead of one twice the breadth. A single spiral wound with nearly three times the number of turns gives a greater resistance than one a third of its length, but the increased resistance is much less than one would expect. In addition, at intermediate heads, all the curves seem to approximate, for what reason it is difficult to say.

The pitted type of thickening allows a greater rate of flow at high heads than do the annular or spiral, but in all cases the rate of flow at a low head is below that of the annular and spiral types.

It is noticeable that the rate of flow drops very considerably when the first 90 pits are cut out of the solid rubber, but that the addition of a second series of alternating pits does not affect the rate of flow to the same extent.

The first big drop occurs because of the change from stream line flow to turbulent flow. The addition of the next 90 alternating pits serves to decrease the rate of flow to a slight degree, because

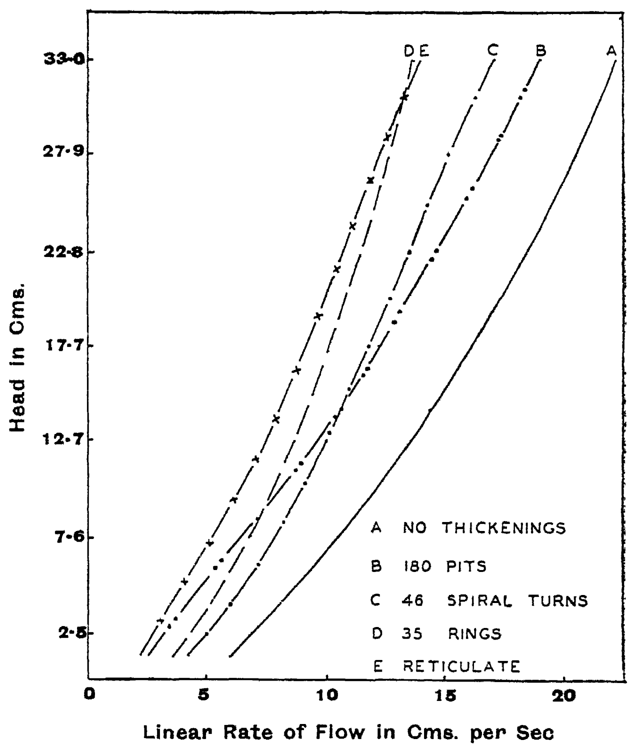


FIG. 6.—Comparison of the effect of Spiral, Annular, Pitted and Reticulate thickenings on the rate of flow.

of the further breaking up of the stream of water, and the formation of eddy currents round the new pits. In these pitted types we get a serpentine flow of the water between the pits. Eddy currents are only formed in the vicinity of these pits, and the rate of flow is not affected to so great an extent at a high head as with the annular thickenings.

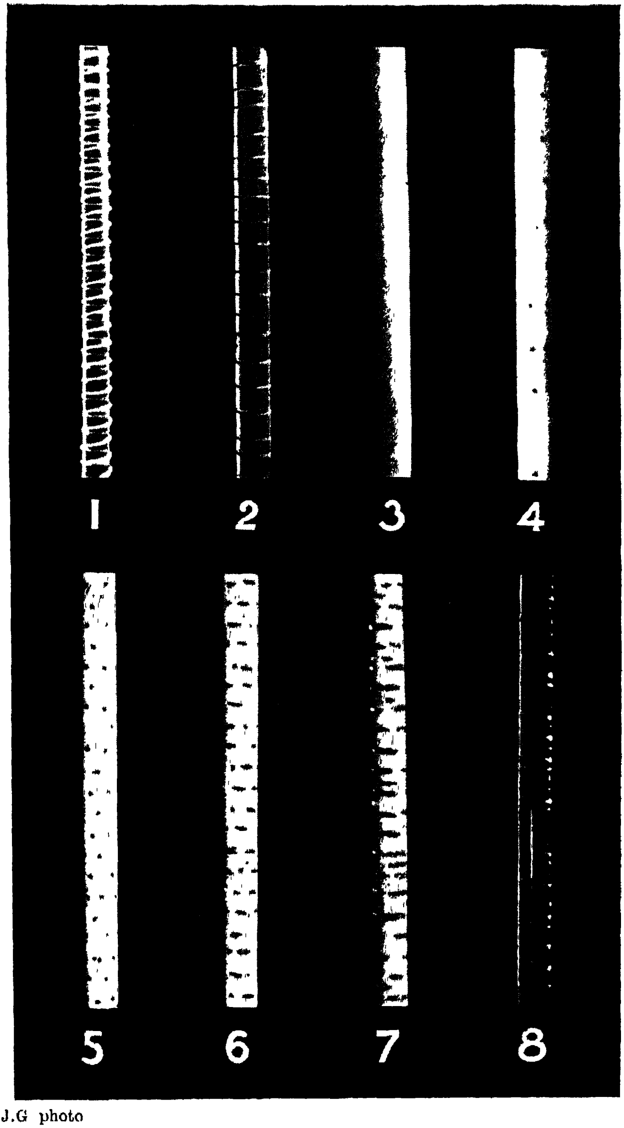
With the extreme reticulate type of thickening the rate of flow is greatly retarded, giving values at a head of 33 cm. which are very close to those obtained for the annular type of thickening at a similar head. At a head of 1·27 cm. the reticulate thickening gives the greatest retardation of flow for the whole series of experiments. Eddy currents exercise a great effect in this case, and are more in evidence at low heads for reticulate thickenings than they are for similar heads using annular thickenings.

Conclusions.

The results of these experiments indicate that in models of wood vessels the rate of flow of the water in general is lowest when reticulate thickenings are used. The annular type exercises the next greatest effect, followed by the pitted type. At heads above 10 cm. the spiral thread has a more pronounced effect on the rate of flow than has the pitted type, but otherwise spiral thickenings least retard the rate of flow. Since all the above types of thickening occur in the wood vessels of plants it is reasonable to assume that they would exercise a similar relative effect on the rate of flow of the sap in the vessels.

A biological explanation of the type of thickening occurring in wood vessels is possible. Annular vessels are developed early and they require a minimum amount of thickening material. They are highly flexible, and since they develop early in thin walled tissue, there is no danger of their being occluded by the pressure of surrounding harder tissues. Annular vessels are narrower than the vessels of the metaxylem, and may be expected to offer greater resistance to flow. Spiral vessels also develop early, and these offer less resistance to flow. As the pressure of the surrounding tissues increases, the plant develops closer spirals and finally reticulate or dotted vessels which are comparatively rigid. As the conducting area is now larger the resistance to flow is a factor of less importance than is rigidity. The higher resistance to flow in reticulate vessels at low heads as compared with spiral vessels is also far more than made good by their increased diameter. At low heads diameter is far more important than the character of the internal surface.

In conclusion, I would like to acknowledge the helpful suggestions and criticisms from Professor Ewart during the progress of the work.



B J.G photo

Types of Thickenings in Wood Vessels.

Summary.

1. Experiments have been carried out using models of wood vessels to test the comparative effect of the different kinds of thickening on the rate of flow.

2. The results of these experiments show that reticulate and annular thickenings retard the rate of flow most. At high heads pitted thickenings offer less resistance to flow than does the spiral type, but at low heads spiral thickenings offer the least resistance to flow of the whole series.

3. It is considered possible that the types of thickening in the vessels of plants might have a similar relative effect on the rate of flow of the sap.

References.

(1) H. H. Dixon.—Transpiration and the Ascent of Sap in Plants, p. 97, 1914.

(2) A. J. Ewart.—The Ascent of Water in Trees. *Phil. Trans. Roy. Soc. Lond.*, cxcviii., p. 41, 1905.

Description of Plate XII.

Fig. 1.—Type of Spiral thickening.
Fig. 2.—Type of Annular thickening.
Fig. 3.—Solid rubber thickening.
Fig. 4.—Pitted thickening.
Fig. 5.—Pitted thickening; pits doubled and alternating.
Fig. 6.—Round and elongated pits.
Fig. 7.—Elongated pits.
Fig. 8.—More typical Reticulate type of thickening.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II., 1930.]

ART. XIX.—*The Factors controlling the Distribution of Trees in Victoria.*

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(With Plates XIII.—XX.).

[Read 12th December, 1929; issued separately 13th March, 1930.]

Introduction.

The Distribution of Trees has a twofold interest, scientific and economic. These two are closely related. Trees are the dominant members of the plant community of which they form a part, and whatever laws or factors control their distribution also control, in whole or in part, the other members of that community. The various associations of which the trees form such a conspicuous part have not been discussed herein, although the majority of those occurring in the State have been investigated, and these will form the subject of a later paper. Nor have the various forest types been discussed, although all of these have been studied. A forest type may be considered an ecological unit where only the trees are recognized. However, the forest type brings in other considerations which do not enter into ecological work. The recognition and definition of these types is necessary for the purposes of forest management, and these also will form the subject of another paper. The present work aims at being basic either for the student of botany or of forestry, but it is this latter point of view which has been kept mostly in mind in the present paper. A study of our trees and their distribution shows that only a comparatively small area of the State is clothed with good forests. The investigation has shown that the mere setting aside of large areas of country for dedication as forests may not achieve anything at all. Nature may not have produced merchantable timber on those areas. These areas may be capable of producing timber of high commercial value, but before that can be achieved the species most suited to those areas must be found. Hence the importance of knowing all the factors of the environment, which is after all the work of pure science. Species must be introduced not only to augment our national wealth but also to clothe those areas where Nature has not provided a timber producing tree. To plant species without reference to the conditions of their natural habitat is to invite disaster. Very valuable time may be lost in such a

proceeding. While we are richly endowed with hard, heavy, durable timbers we are very deficient in softwoods. Of these latter, the two most important genera are *Pinus* and *Picea.* In general these two differ markedly in their requirements as regards environment. Many species of pines are what are known as thrifty, that is, they can grow where conditions are very unfavourable. Thus we have the outstanding example of *Pinus sylvestris,* of which such great use has been made in Europe. Other prominent examples are *P. pinaster* in the South of Europe and *P. rigida* in U.S.A. The genus *Picea,* on the other hand, does not produce thrifty trees. Its species usually demand very favourable conditions of growth. In comparing then the natural environment of the species of the two important genera with conditions in our own State we may be reasonably sure of establishing successful forests artificially.

The study of the environment of our trees has taken a long number of years to accomplish. The whole of the State has been covered, but not every part studied with the same detail. It was originally attempted to examine the State at intervals of 20 miles and this has very generally been adhered to. In the northwest, where the factors affecting distribution do not vary, the intervals have been much wider, but where the factors have changed rapidly the intervals have been much closer. Every zone of rainfall has been studied and also every geological formation. Almost every species has been seen in its native habitat, and the range of most of them has been ascertained. These ranges will be given in conjunction with forest types.

Nomenclature should not normally enter into an ecological discussion, but the very great differences of opinion which exist, particularly in regard to our principal genus, *Eucalyptus,* demand some statement as to the use of specific names. In general, a conservative use has been followed in this work. There is nothing more confusing to the field worker, be he either ecologist or forester, than to find that there is no unanimity of opinion regarding the species with which he is working. It is preferable that a species should be wide, admitting varieties, rather than that there should be a large number of species differing but little. The history of all the species of *Eucalyptus* has been investigated by the author and this will be given when the ranges of the species are published. In the following pages it has seemed best to use *E. amygdalina* in its wide sense as formerly understood. The same applies to *E. capitellata.* The widespread *E. viminalis* occurs in two very well marked varieties, (a) *alba,* which has a long clean bole and is found in the wetter parts of the State, and (b) *arenaria,* which has persistent rough bark and which is almost always a broad-crowned, short-boled tree. Species have been selected for illustration of the influence of the various factors, so that there shall be no ambiguity.

Classification of Factors.

Every student of plant distribution recognises that external influences play an important part in the distribution of plants, but just how much influence each factor exerts is yet a matter of discussion. This difference of opinion arises from many causes. It is partly due to the newness of this branch of botany, and it is but natural that there should be differences according to the view-point of the investigator. Divergent opinions arise, too, from the fact that botanists are working in widely differing centres and therefore with conditions widely different. It is not unlikely that, under such circumstances, the factors themselves are not comparable as regards their influence on the plant. Differences of opinion, too, arise from the fact that there is a lack of detailed information concerning the factors themselves. This is notably the case with climate. The investigation of plants calls for fuller information. Lastly, investigators differ, it may be, because they fail to recognise that all plants in an area are not equally affected by the factors of the environment. These appear at the moment to be the chief causes of varying conclusions.

In regard to investigators arriving at different conclusions regarding the same factor, reference may be made to Warner (1). When speaking of Texas soils, he says, "No ecologist in travelling through eastern and central Texas could fail to notice how closely plant formations follow certain types of soil in this region." Hutchinson (2), on the other hand, working in another part of the same continent, says, "The original composition of the soil is seldom a limiting factor, at least in so far as the forests of Ontario are concerned." Both of these investigators are no doubt correct in so far as these areas are concerned. The science has not progressed far enough for generalizations to be made. It is highly probable that in the two cases mentioned two totally different types of plants, in so far as their response to their environment is concerned, are involved. In this State of Victoria, there are outstanding examples of plants which appear to be wholly independent of the environment over very wide tracts of country, and very erroneous conclusions might be drawn from them. Thus *Goodenia ovata* occurs anywhere from sea level to almost subalpine elevation; it is found in every rainfall from 25 inches to 60 inches; it grows on every kind of soil; and it will thrive equally as well in the open scrubs as in the mountain forest. Of still wider distribution are *Wahlenbergia gracilis* (Campanulaceae) and *Vittadinia australis* (Compositae). Such plants may be very conveniently termed versatile wides. It is more than probable that a large number of the wides of the Age and Area Hypothesis (3) are versatile wides. On the other hand, there are many plants which are definitely restricted in

their distribution because they are not independent of their environment. It is the aim of ecological research to discover these limiting factors. Some of these are very obvious, but others are very obscure.

With regard to lack of information, Livingston and Shreve (4) say, "Climatological methods and climatological interpretation, as so far developed, are woefully inadequate for the solution of problems dealing with the control of plant distribution." They say, further, "It may readily happen that some of the most satisfactory methods for ecological climatology will be strenuously opposed by students of climatology, as this special science has been hitherto developed, but such students may remember that the main reason why greater progress concerning the relations of climate to organisms has not been made lies in the fact that those interested in climate have seldom been seriously interested in physiology, while most writers in physiology have had little active interest in climate."

It has also been suggested that differences of opinion may arise from the fact that all plants, in any community, are not affected to the same extent by the factors of that environment. In any habitat plants are found which occur also in other habitats. The habitat is the sum total of a large number of factors and all of these may not be known. Each factor of the habitat contributes its quota to the conditions existing there. No one habitat can be defined in exact terms, and the precise reason why each individual enters the habitat is not the same for all. Each enters because of some individual factor or combination of factors. Thus if we consider what may reasonably be called a climax association, e.g. the Fern Gully Association, we see a number of trees which might be considered as forming collectively a very definite unit of vegetation; but when we analyse the distribution of each individual species occurring there, we find that what appears to be a very definite association is, after all, only a compromise. In this Fern Gully Association we have *Eucalyptus regnans, Nothofagus Cunninghamii, Acacia dealbata and Acacia melanoxylon* among others. Of these, *Nothofagus Cunninghamii* has the most restricted distribution, being confined to the sheltered and moistest areas. *E. regnans* passes from the valley floors to the crests of the ridges, and with it is associated the hill tree fern, *Alsophila australis.* Its range is restricted mainly by rainfall and soil. *Acacia dealbata* evidently enters these gullies on account of abundant soil moisture. It passes out from these gullies to the banks of the streams arising in them. This tree species passes right into areas of comparatively low rainfall and into areas far removed from mountains, but its habitat, so far as soil conditions are concerned is essentially the same. Shelter means nothing to it, yet this is essentially the factor affecting *Nothofagus Cunninghamii. Acacia melanoxylon* reaches its maximum development as regards

individual specimens in these gullies, yet what factor of the environment favours its entrance? It occurs among other widely differing habitats on the basalt plains, where it is a very poor specimen of a tree compared with its development in the gullies. In the plains, *A. melanoxylon* is associated with *Banksia marginata*, but this latter never enters the fern gullies. Instead, it occurs on the Tertiary sands, which are very dry in summer and which are covered with a very xerophytic vegetation. These two species, then, are associated on some habitats, but not on others. This gully association, which appears to be a unit, is actually not so, since all its components are not equally distributed. Any association of plants, then, cannot be regarded as a unit as is a species, as has been suggested, but must be regarded merely as an assemblage of wandering units, not held together even by a common bond of the habitat itself, but rather a company of dissimilar units accidentally united. This may seem to be a new conception of a habitat, but it appears to be the only rational one from a study of the range of the individual species forming any association. If we study any association at all, we will find that in no case do we find that all members have an equal range. The truth is, that each species has its own range, and within that range conditions pass from the most favourable to those that are inhibitory. This is seen to be the case with the red ironbark, *E. sideroxylon.* In the Gippsland areas it occurs sparsely though fairly widely distributed. In the Bendigo area, where conditions are drier and hotter, it forms pure forest. Its frequent associate in this latter area, red box (*E. polyanthemos*), accompanies it to Gippsland, but not so its other associate, grey box (*E. hemiphloia*). Likewise, its associates in Gippsland do not enter the Bendigo zone. Each species of any habitat has its own specific range and a community may be regarded as an area where a sufficiently large number of species overlap so as to give that area a distinctive appearance. Each individual is present because of some particular set of conditions, and hence we cannot regard the habitat or the community as anything individualistic.

As time has progressed successive workers have added more and more to the factors which control the distribution of species. We are yet far from knowing all, but each contributes his quota. Schimper (5) stressed climate, almost to the exclusion of geological factors. He says, "The differentiation of the earth's vegetation is thus controlled by three factors—heat, atmospheric precipitation (including winds), soil. Heat determines the flora, climatic humidity the vegetation; the soil as a rule merely picks out and blends the materials supplied by these two climatic factors, and on its own account adds a few details." That climate is not the only factor, or at least as important as Schimper says, is indicated by the statement of Clements (6) in regard to North America. "It will suffice," he writes, "to point

out that no climatic chart, no matter how accurate, can hope to outline the vegetation of North America." The most recent worker, Tansley (7), considers that "Factors may be conveniently grouped in four classes, according to the nature of the environmental conditions to which they give rise, namely, climatic, physiographic (topographical factors, etc.). edaphic (soil) and biotic (the effect of animals, including the whole of man's influence on natural vegetation)." In his other work, Tansley (8) has set out in greater detail these factors. Under the heading Physiographic, two sub-headings are included, Geology and Topography. This does not appear to be a natural sequence, for topography is the outcome of physiography and therefore is correctly placed as a subdivision, but physiography in its turn is the outcome of the geological past and therefore it would follow that physiography ought to be placed as a subdivision of geology. The present physiography of the earth's surface is due mainly to the following causes: Subsidence and elevation, varying lengths of time that have elapsed since uplift occurred, varying hardnesses of the constituent rocks of the earth's surface, and the juxtaposition of hard and soft rock masses. Since all these agencies are purely geological, it seems fitting to make physiography subordinate to geology in the classification of factors. Physiography is concerned with the forces that have moulded the rock masses into their present configuration, which result we know as Topography. But physiography is not the only result of the geological past, for so also is soil. Soil results from the disintegration of the rock masses. Some rocks weather very rapidly, but others are highly resistant for various reasons. The quality of the resulting soil is primarily governed by the chemical and physical composition of the rock from which the soil is derived. Thus we have the dark rich chocolate soil arising from the dacite, and the poor infertile soil arising from the sandstone. No matter, however, what the climate may be, if the soil be unretentive or too retentive as regards water, or if it contains abundant mineral nutrients or be very deficient in this respect, the plants of the area concerned will be materially affected. This is to be seen throughout the State. It seems quite fitting, therefore, that soil should be made a subdivision of geology, of equivalent rank with physiography. Each of these two subdivisions lends itself to further subdivision as will be discussed later.

In discussions regarding the distribution of plants, geology as a factor in affecting such distribution has very frequently been but little considered. It has already been remarked that Schimper (5) stressed climate to the exclusion of other factors. This is borne out by another statement of his in reference to the temperate zone. He says, "Atmospheric precipitations determine, in the first place, the distribution of woodland, grassland, and desert, also the vegetative characters of their individual

formations within the temperate zones." It will be noted that there is no reference to any geological factor, although it will be shown later that the soil factor influences the type of vegetation very materially. Schimper regards the main formations as given above as due to rainfall. Grassland, for instance, he considers to be the outcome of a particular climate in which the precipitation is fairly evenly distributed throughout the year. It is a remarkable fact that the large grassland areas of the world are wide open plains. In this State, both the northern and southern grassland areas are plains, and wherever these plains abut on hilly country, the grassland ceases and trees occur, no matter what the rainfall may be. This is well seen to the north of St. Arnaud. The plains are treeless over extensive areas, but as soon as hills are reached various species of trees occur, and in a few miles forest conditions are reached. The differences in elevation are very small. At Bacchus Marsh trees occur abundantly on the Permo-Carboniferous and Ordovician rocks,

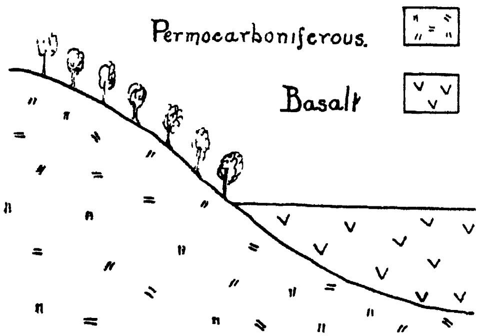

FIG. 1.—Trees growing on the Permo-Carboniferous Rocks, but not on the Basalt.

but none occurs on the small adjacent basalt plains, although these are almost surrounded by trees (Fig. 1). Numerous other examples might be quoted to show that climatic factors are not the only factors concerned. A good illustration also occurs in the Melbourne area. Here there are three geological formations, all extensive, all enjoying the same climate and all differing but little as regards their elevation. Any differences in vegetation therefore cannot be due to climate or to elevation. The three have markedly different associations, so marked, indeed, that a geological map defines the respective associations. One is grassland, one is scrubland, while the third is forest. Soil is the controlling factor, not climate. Grassland, as far as this State is concerned, is not controlled by climate. There does appear to be, however, a very close connection between grassland and physiography or between grassland and soil, or it may be between all three. Grassland is essentially associated with plain country.

In this State there are the basalt plains of the west and the Tertiary plains of the north, and also the High Plains of the northeast. These areas are well marked out physiographically. The hill country of this State and similar parts of the adjoining States favour woodland. From what has been said, it is clear that geology plays an important part in the distribution of the various formations in this State.

Under the factor Biotic may be included quite a number of phenomena. Up to the present this factor has had rather a restricted meaning. Practically only the influence of animal life on plant life has been considered. Theories such as Willis's Age and Area Hypothesis must surely be included in any discussion on the present distribution of plants. Under the Biotic factor, too, must be included fire, for although fire may be caused by natural means, there is no doubt that in newly civilized countries forest fires are now both much more frequent and much more devastating than formerly. It is not very probable that the native animals have had much to do, if indeed anything at all, with the distribution of our trees. The seeds of our eucalypts are very small and are borne very high up on some of our trees, and are not any inducement for animals to obtain them. Under Biotic factors, too, must be included the virility of the species or genera of trees. Some are much more aggressive than others, and this is an important feature in their distribution.

The factors, then, affecting the distribution of the trees in this State will be discussed under the three headings, Climatic, Geological, and Biotic. These have been further subdivided, as is shown in the following classification.

Factors controlling Distribution of Plants.

A. Climatic: (*a*) Rainfall:
- 1. Annual Precipitation.
- 2. Monthly Distribution.
- 3. Reliability.

(*b*) Evaporation.
(*c*) Temperature.
(*d*) Ocean Currents.
(*e*) Wind.

B. Geological: (*a*) Soil:
- 1. Physical Constitution.
- 2. Chemical Composition.
- 3. Water Content.
- 4. Subsoil.

(*b*) Physiography:
- 1. Elevation.
- 2. Contour.
- 3. Slope.

C. Biotic: (*a*) Fire.
(*b*) Virility.
(*c*) Age and Area.

A.—Climatic.

Victoria has a very wide range of climate, containing as it does every phase from sub-alpine to semi-desert, and it naturally follows that with these widely differing climatic conditions there are naturally widely differing plant communities. All these communities, however, as already indicated, are not entirely due to climatic effects. Although the area of the State is comparatively small, being 87,000 square miles, several distinct climates may be recognised. Griffith Taylor (9) has pictured Victoria as belonging to two different climatic divisions; the boundary line between the two being approximately a north-easterly line running from Wilson's Promontory to Tallangatta. The line of demarcation between these two divisions cuts through the South Gippsland hill country, which is itself a very distinct unit. Taylor admits that the boundaries are somewhat arbitrary. They are indeed. The line passes right through the alpine area. Thus we find that Mt. Howitt, 5718 feet, is separated from Mt. St. Bernard, 5060 feet, although they belong to the same range and enjoy the same climate. The western portion of the alpine area (e.g. Mt. Howitt) is included with the Mallee in the other division. The alpine area is just as distinct a unit as is the Mallee. No division of the State into climatic districts could be more artificial, and the work serves no useful purpose in the study of the distribution of plants. All of the State east of this line he pictures as belonging to the Canberra zone, which passes up along the east of New South Wales. The other zone is known as the Victoria division and contains all of Victoria lying to the west of this line. Following the work of Diels (10), Taylor has given in the work quoted above (9) a vegetation map covering these two climatic districts so far as Victoria is concerned. The two maps by Taylor, the climatic and the vegetational, are rather inconsistent. The district known as the Canberra contains alpine areas as well as coastal plains. In the vegetation map the alpine area is shown as such, but no alpine climatic area is shown on the other map. The remainder of the area of the Canberra climatic district is shown as having the same vegetation as Southern Victoria. This latter is shown as passing down into Tasmania. This is assuming too much. The vegetation of South Gippsland is similar to that of the Otway area and this type of vegetation does pass down into Tasmania; but the vegetation of eastern Victoria is of a particular type which is discussed under Ocean Currents, and this does not pass into the southern State. It is true that the forest vegetation of these two areas is superficially similar, but the species of the two differ both in the dominants and the sub-dominants. It is not proposed to give in this work a vegetation map, but it may be noted here that the vegetation of the area given by Taylor as Rain Forest is fairly complex, containing

as it does mountain forest, lowland savannah and dense jungle communities. The western section given as the Victoria district is more happily drawn in that the northwest of the State is included with South Australia, the northern plains with the Riverina, while the Otway area is associated with corresponding areas in Tasmania. The grassland of the Western District is also recognized. Climate does express itself most forcibly in our vegetation, and hence there should be a close approximation of a climatic to a vegetation map. Climate is defined as the sum total of weather conditions. These conditions are very variable and are all more or less operating at once. Just how much each factor affects the distribution of plants is very often difficult to determine. We cannot experiment with the factors of climate, varying one at a time and keeping the others constant, and therefore recourse must be had to comparing one area with another and noting the fluctuations of both vegetation and factors of climate. All the factors do not usually fluctuate to the same extent over any given area and it is from these unequal variations at various places that deductions may be drawn.

(a) RAINFALL.

The average annual rainfall, with which aspect we are most accustomed, while in itself an excellent guide to the vegetation of an area, yet is not sufficient for a complete understanding of the effect of rainfall, for the same average rainfall may produce entirely different types of vegetation. The distribution of the average rainfall is an equally determining factor. In Australia we have pronounced examples of rainfall distribution. At Darwin, for instance, the bulk of the rain is received in the

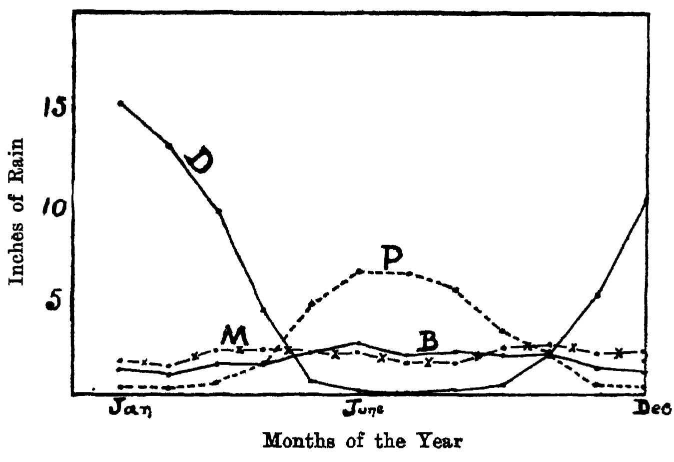

FIG. 2.—Monthly Distribution of Rain for Darwin (D), Perth (P), Melbourne (M), and Bendigo (B).

summer and very little in winter (Fig. 2). For the six summer months, October to March. 55·65 inches of rain are received, while only 6·07 inches are received in the months April to September. Precisely the reverse of this happens at Perth. At this station, 5·17 inches are received during the six summer months, while 29·15 inches fall during the six winter months, April to September (Fig. 2). Over the greater portion of Victoria the distribution is a very modified winter type, as reference to Fig. 2 will show. Indeed, it would be more correct to say that our rainfall is more a modification of the even distribution rather than of the winter type. In Fig. 2 the rainfall for a typical inland station, Bendigo, is given. At this Station 8·71 inches fall in the summer, while 12·79 inches are received during the six winter months. Melbourne represents an even distribution of rainfall, as reference to Fig. 2 shows. At this station actually slightly more falls in the six summer months than during the winter, the amounts being 13·10 inches and 12·68 inches respectively. Besides these two conceptions of rainfall, the Average Annual and the Average Monthly, there is a third point of view. No matter what the average or the distribution may be, if the rain be not regularly received vegetation will be very materially affected. Regularity has more effect on evergreen trees and shrubs than upon annuals and perennials. The two latter may remain dormant during periods of dryness, but the former are always subject to transpiration, no matter what the season may be. Hence prolonged dryness, if it passes a certain limit, must eventually cause the death of the trees or shrubs. This happened during the dry periods of 1923 and 1927.

Rainfall, then, will be considered from the three points of view: Average Annual Precipitation, Distribution, and Reliability.

(1) *Average Annual Precipitation.*

Our lowest rainfall is in the northwest of the State, where a little over 10 inches is received, while our highest is in the Cape Otway area, where at one station over 70 inches are received. The areas affected by these two extremes are very small, but between these two are very extensive areas receiving intervening amounts. For the purposes of tree distribution, the rainfall areas group themselves into four classes: 40 inches and over, 30 to 40 inches, 15 to 30 inches, and below 15 inches (Plate XIII.).

Above 40 inches the vegetation is the same up to the extreme limit of 70 inches. There is only one 70 inch area, but there are three 60 inch areas. Only one of these is fairly extensive, and this runs from near Wood's Point to Mt. St. Bernard. The other two areas are Blackwarry in South Gippsland and Beech Forest, the latter including the 70 inch area. The total area of the State receiving over 60 inches amounts to only 1·8 per cent. of the State (11). The 40 inch isohyet may be regarded as a critical

one for some of the most important tree species of the State. The tall timber-producing species, *E. regnans* and *E. gigantea,* do not pass below it, while the heavy timbered species, *E. sideroxylon, E. polyanthemos, E. hemiphloia,* and *E. rostrata,* do not pass above it. The total area receiving 40 inches or more amounts to only 14 per cent. of the State. Four separate areas are enclosed by the 40 inch isohyets, and of these four the largest and most important is that associated with the high mountains of the north-eastern part of the State. All four are important, however, from the fact that they carry high forest. Three of the areas, the Gippsland, the Otway and the North Eastern, carry the tall eucalypt, *E. regnans,* but this species does not occur everywhere throughout these areas. The fourth area, which lies around Trentham, although carrying high forest, does not contain *E. regnans.* Besides this very tall species, however, there are a number of other species of Eucalypts that also grow to immense size within the 40 inch isohyet, although they are not confined to that region. In the regions of lower rainfall they never attain the size that they do in the higher rainfall areas. The following species commonly reach very great size: *E. obliqua, E. capitellata, E. Sieberiana, E. goniocalyx, E. rubida,* and even *E. amygdalina,* which is quite commonly a very small tree. It is in this area, too, that the variety *alba,* of *E. viminalis,* reaches very great proportions. Not all trees, however, that cross from the lower rainfall areas into the higher are affected as regards size. The long-leaved box, *E. elaeophora,* for instance, which is always a poor tree, does not increase in size in the higher rainfall areas.

This heavy rainfall area is of great interest because it forms a meeting place of the Malayan and the Antarctic elements of our flora. Where these meet we find the tallest of our trees and here, too, our finest forests. In the more favourable parts of this area the tree ferns, *Alsophila australis* and *Dicksonia antarctica,* reach great size, and these among many others represent the Malayan element. Among trees which are of Malayan origin is the Sassafras, *Atherosperma moschatum.* Growing along with these is the typical antarctic species *Nothofagus Cunninghamii.* The genus *Nothofagus* is found in Tasmania, New Zealand and Chili. The genus *Lomatia,* represented by *L. Fraseri,* also extends to South America. Both of these are exclusively southern. Both the Malayan and the Antarctic elements are strongly represented. There is present besides these two an Australian element. This triple association does not cover the whole of the areas enclosed by the 40 inch isohyets, but only very restricted portions of them. These areas, from a forest point of view, are the most important in the State. They are, in the main, typically forest land, although within them are natural agricultural areas. They are important also because they form the catchment areas of our chief irrigation, hydroelectric and water supply systems.

The country lying between the 30 and 40 inch isohyets is in the main true forest land, although the forests occurring there may not be regarded at present as merchantable. Portions of this area have been selected for settlement, but not always with success. This area occupies 16 per cent. of the State, and this, together with the high rainfall area, makes 30 per cent. of the State true forest land. Not all of this is carrying forest, and of the forested area only a percentage is merchantable. This zone, between the 30 and 40 inches, is the home of a large number of rough barked, widely distributed species such as *E. obliqua*, messmate; *E. capitellata*, brown stringybark; *E. eugenioides*, white stringybark; *E. Muelleriana*, yellow stringybark; *E. Sieberiana*, silver-top; *E. macrorrhyncha*, red stringybark; *E. goniocalyx*, mountain grey-gum; *E. amygdalina*, peppermint; and *E. dives*, broad-leaf peppermint. This zone might well be called the stringybark zone. It is the home of the widest-spread forest type we have, the Messmate-Peppermint type. These species, however, find their way abundantly into the higher rainfall areas wherever the soil or other conditions are unfavourable for the growth of those species which are restricted to a high rainfall. They may also be found at a lower rainfall, but they never reach the same size as they do in the 30-40 inch zone, nor are the forests so dense. Below 30 inches conditions are not favourable for the best development of the above species.

Between the isohyets 15 and 30 inches no less than 48 per cent. of the State is enclosed. This area is agricultural in the main and is eminently suited for that purpose on account of its fertility, its lack of contour, and its climate generally. It has been widely cleared and evidences of its tree distribution are fast disappearing. Large portions of it were, however, either devoid of trees as in the western plains, or were in savannah formation as in the northern parts of the State. In both of these areas the eucalypts are often replaced by species of *Casuarina*, as for instance *C. stricta* on the basalt plains, and *C. lepidophloia* in the northwest. In this region, however, are found our most important heavy-timbered species, *E. sideroxylon*, red ironbark; *E. leucoxylon*, white ironbark; *E. hemiphloia*, grey box; *E. melliodora*, yellow box; and *E. polyanthemos*, red box. These are not confined to this zone, for they make their way into higher rainfall areas whenever conditions for their entry are favourable, but the best forests containing them are found in the 15 to 30 inch zone. The areas containing these forests are not extensive and the land carrying them may be regarded as true forest land, mainly on account of the high quality of timber that it carries. The percentage of the State occupied by these forests is only small. These forest areas will be considered in a subsequent publication, both as regards area and type.

The area below 15 inches coincides generally with what is known as the Mallee. This is a very extensive area enclosing no less than 22 per cent. of the State. Physiographically, the area consists of an open plain, broken only by low sand ridges. These sand ridges are not sand dunes in the ordinary sense of the word, for the material of which they are composed is not quartz only, but other minerals as well. They are at times quite loose, but at other times are quite compact. These ridges are covered with species of *Callitris,* and this is one of the few instances where the eucalypt is not the dominant tree. In the extreme northwest the rainfall is only a little above 10 inches. The Mallee is really a transition from desert to better conditions. The eucalypts, which themselves are known as mallees, are all generally small and they are the dominant vegetation over the greater part of the area. The individual mallee consists of an enlarged butt from which several shoots may arise (Plate XVII.B). When the shoots are slender it is known as whipstick mallee, but when the trees are large it is then known as bull mallee. The species are very variable and this has caused the nomenclature to become very involved. The mallee is usually associated with the poorer classes of soil, while the better classes of soil are usually occupied with other species. Associated with the species of *Callitris* in the northern part of the Mallee is *Casuarina lepidophloia,* Belar. Both may occur together or either may form pure forest. Both of these are very valuable, but it is very doubtful if the areas where they grow can be classed as forest land, since the soil is very fertile. Other tree species which are present are *Myoporum Dampieri, Pittosporum phillyraeoides, Hakea leucoptera,* and *Heterodendron oleifolium.* These are all strongly xerophytic. Besides these trees the two eucalypts, *E. rostrata* and *E. bicolor,* also are found, but their distribution is not governed by rainfall, and they cannot be regarded as members of the Mallee community. This area is, on the whole, agricultural, but there are areas unsuited for that purpose, and as these cannot be utilized for forest purposes they must be regarded as waste land.

(2) *Monthly Distribution.*

As has already been remarked, a very modified type of winter rainfall prevails over the greater part of the State, while over the remainder an even distribution occurs. In the former case, the wettest month is June and the driest is either January or February. In the even distribution the wettest month is usually towards the end of the year. The following table gives the monthly rainfall for representative stations throughout the State:—

TABLE I.—AVERAGE MONTHLY DISTRIBUTION OF RAIN IN VICTORIA

Station	Monthly Averages in Points												Total inches
	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep	Oct	Nov	Dec.	
Mildura	55	78	75	63	107	138	84	115	112	103	81	83	10·94
Swan Hill	62	75	82	94	139	168	112	139	138	113	98	113	13·33
Yarrawonga	125	116	154	146	193	237	172	199	182	179	138	134	19·75
Omeo	209	199	205	157	194	227	208	199	258	260	209	237	25·29
Melbourne	191	172	219	219	217	207	185	187	245	263	224	220	25·58
Orbost	288	237	235	260	264	308	265	232	303	300	223	272	31·87
Portland	137	133	164	259	368	412	419	411	343	285	193	179	33·06
Trentham	197	187	284	260	430	534	441	449	442	340	270	254	40·88
Blackwarry	389	354	394	476	502	642	498	590	583	453	354	257	55·92
Wood's Point	311	228	355	353	524	759	661	696	665	571	403	403	59·29
Beech Forest	312	219	399	542	671	837	759	762	731	590	434	351	66·37

The last three stations are representative of the heavy rainfall areas. It is this comparatively even distribution that provides the conditions necessary for the rich development of our temperate rain forest. Although more rain falls in the winter months than in the summer, yet sufficient rain falls during the summer to prevent any xerophytic habit arising. This is typically a temperate rain forest. In this heavy rainfall area there are two distinct types of soil controlling the vegetation found there; one is favourable to the development of the rain forest, while the other is unfavourable. In the favourable soil areas the trees reach a height of over 300 feet, the record being 326 feet. The rapidity of growth and the volume of timber produced are both indicative of the favourable conditions of growth. The trees form close-canopied high forest, which is, however, very broken, as is usual with virgin forests. Associated with these tall eucalypts are a number of rain-loving trees and shrubs, and in the gullies the extremely delicate filmy ferns belonging to the genera *Trichomanes* and *Hymenophyllum* grow in profusion. A tropical colour is lent to these forests by the presence of lianes, but these are not numerous. All of this vegetation is indicative of an abundance of water. The presence of the antarctic element is also a witness that there is no deficiency of water. Further evidence that the rainfall is abundant may be found in the fact that the vegetation in the gullies consists of several stories. An increase in the amount received or a greater proportion falling in summer would not disturb the existing vegetation, since latitude is now the controlling factor. Growth is at a maximum, for both soil and rainfall present the most favourable conditions possible.

Where, however, the soil is not favourable for the production of *E. regnans* forest and its associates, it is also improbable that there would be any disturbance of the existing vegetation even if the rainfall were higher or more were received in summer. We find *E. elaeophora* ranging right down to 21 inches at Stawell

and still lower at Mt. Arapiles. It also occurs in the heavy rainfall areas as at Wood's Point, where the rainfall is 60 inches. This species is never a timber tree; its bole is always short and carries a large spreading crown. Its presence everywhere indicates the unfavourable soil conditions. Soil is the limiting factor, and any increase in the amount of rain received during summer would not affect its unfavourable influence. This species is also associated with the broad-leaved peppermint, *E. dives*. These are found together at many places, as, for instance, Wood's Point and Daylesford. Rainfall can only produce its effect when the soil is responsive and receptive.

In the areas with a rainfall below 40 inches, however, the monthly distribution has undoubtedly a very marked effect on the eucalypts present. A large percentage of the rain falling in winter is lost so far as the trees are concerned owing to their dormancy during that season. In summer less rain falls than could be utilized by an optimum vegetation. Below 40 inches the plants associated with the eucalypts are markedly xerophytic.

In the southwest and the southeast we have the most marked effect of the distribution of rain. In the southwest the forest extending westward from Portland consists of *E. capitellata, E. vitrea,* and *E. viminalis,* and is much inferior both in the height of trees, quality of timber, and number of species, to that occurring in the east. This latter forest consists of *E. capitellata, E. Muelleriana, E. eugenioides, E. Stuartiana,* and *E. Sieberiana.* There is also a little *E. globulus* present. Both of these forests occur on Tertiary sands, and both have stringybark as the dominant tree. The rainfalls are very similar, Orbost having 31 87 inches and Portland 33·06, but the distribution of each is very different. At Orbost, the winter and summer falls are about the same, being 16·32 and 15·55 respectively. At Portland, on the other hand, the winter rain is 22·15 and the summer 10·91 inches; that is, the summer is less than half the winter. It is this summer rain at Orbost that is in part responsible for the better forest in the southeast.

(3) *Reliability.*

While both the total amount of rain falling and its distribution through the year have a profound influence on the character of the vegetation present in any locality, the reliability of that rainfall has an equally profound influence. It may be regarded as an axiom that the lowest rainfall periodically received is just as great a determining factor in the vegetation as are the average amount received annually, and its distribution. So far as annuals and perennials are concerned, any year of low rainfall, even if it be exceptionally low, does not affect them greatly, since they are usually only active during the most favourable period of the year, and they pass into dormancy or seed before the unfavourable period arrives. A year of low rainfall merely shortens

their period of vegetative activity. During such years these plants are smaller in size, but the essential functions of flowering and seeding are performed as usual. In very dry seasons it may occur, as happened in 1927, that the seeds do not germinate at all, but remain dormant until the ensuing year. Dry seasons, then, do not interfere with the persistence of annuals, or even perennials. But with trees and shrubs it is entirely different. While it may be true that they, too, are most active during the most favourable period of the year, yet they have to persist throughout the year and right through very adverse dry periods. With evergreens, such as all our plants are, the difficulties for plant life increase. Transpiration goes on, no matter what the rainfall may be, and the plants must obtain, if they are to persist, sufficient water for their needs. If the soil fails to provide the necessary water, the plants must die. Periodic seasons of dryness are constantly recurring, and the plants must be organized to withstand these long dry seasons. If they are not so organized they must cease to exist. Many native plants showed signs of distress during the dry years of 1923 and 1927. If the dryness had continued for a longer period many must have died. The plants had reached the limit of their resistance. The plant is, to a certain extent, plastic, in that it varies its amount of growth with the amount of rainfall received in any season. This is well illustrated in the width of the annual ring, which has indeed been used to study the weather in times preceding the period of taking accurate records. Although the plant is to a certain extent plastic, yet there are limits to that plasticity. A xerophytic plant can take advantage of a very favourable season only to a very limited extent. Xerophytism is brought about, among other means, by reduction of leaf surface and reduction of the number of stomata. Both of these restrictions automatically prevent a large amount of transpiration, even if the water be available in the soil. A reduced leaf surface also limits the formation of carbohydrates, which are necessary for growth. It is probable, then, that the full effect of an abnormal year, such as 21·90 inches at Mildura, is not taken advantage of by the native evergreen vegetation. It is the minimum amount received that determines the existence of the plants of the area. The lowest annual rainfall received at Mildura is 4·71 inches, and the plants must be organized to withstand this. Plants, such as trees, then, are concerned with the minimum amount received periodically. Trees do not bear seed until they are some years old, and therefore, if an adverse season destroyed the tree vegetation, and if a subsequent equally dry season occurred before the trees again bore seed, many species would cease to exist. These conditions were nearly reached in the years 1923 and 1927. The first four months of these two years were particularly dry, and much of the native xerophytic vegetation about Melbourne showed that the limit of endurance was being reached. The average rainfall for Mel-

bourne for these four months, January to April, is 8·01 inches, but in 1923 only 1·92 inches were received for this period, and in 1927 only 3·26 inches were received. It is not likely that any widespread destruction of plant life would occur, for the native vegetation is undoubtedly in harmony with the existing climatic conditions, but, nevertheless, the lower limits reached by rainfall represent about the limit of endurance on the part of the plants. The rainfall records for Melbourne have now been kept for 72 years, and during that time the lowest annual rainfall recorded is 15·61 inches. The average for Melbourne is 25·58 inches. At Mildura, the lowest rainfall station in the State, the average for 38 years is 10·94 inches, while the lowest rainfall received in any year is 4·71 inches. In all parts with a rainfall below 40 inches the periodical occurrence of a dry season has undoubtedly had an effect on the tree distribution.

In areas with a rainfall above 40 inches, the lowest occurring fall does not have any effect where the soil conditions are favourable. In these favoured areas are found the filmy ferns *Trichomanes* and *Hymenophyllum,* which are exceedingly sensitive to dry conditions, and their presence indicates that these areas are not affected by periodic dryness. However, during 1927, in parts these ferns were dry and shrivelled, having that season, here too, reached the limit of endurance. Wood's Point has an average of 59·29 inches of rainfall. The lowest fall recorded was in the drought year of 1914, when 36·81 inches were received. In these areas rain is not a limiting factor. More than sufficient is being received, and this is reflected in the luxuriant growth where soil is not a limiting factor.

The average rainfall, from what has previously been said, does not convey any idea as to the regularity of the amount annually received. Two areas may have the same average, yet one may have a much more reliable fall. A comparison of averages is afforded by means of the Standard Deviation which is given in Table II. for representative stations in Victoria. The Standard Deviation, however, is only a measure of dispersal where averages are comparable, as in the case of Omeo and Melbourne, but where there is a steady variation in the value of the averages as given in Table II., another measure is required for comparison. This is afforded by the Coefficient of Variability, which is obtained by dividing the Standard of Deviation by the average and multiplying by 100. This gives an absolute measure of variation, and, therefore, very widely differing rainfalls can be compared.

From the table it will be seen that the variability of the rainfall is highest in the region of lowest fall. In other words, the lowest rainfall is the least reliable. Generally speaking the degree of reliability increases with the increase of the annual amount received. This uncertainty of water supplies, especially in dry districts, must, of necessity, exclude plants which could exist if conditions were more uniform.

TABLE II.— COMPARISONS OF VICTORIAN RAINFALL.

Station	Average Annual Rainfall	Standard Deviation	Coefficient of Variability
Mildura	10·94	3·6	33·2
Swan Hill	13.33	4·1	30·7
Yarrawonga	19 75	5·0	25·4
Omeo	25·59	4·3	16 8
Melbourne	25 58	4·9	19.1
Orbost	31·87	7·7	15·98
Portland	33·06	4·48	13·6
Trentham	40·88	7·6	18 6
Wood's Point	59·29	12·1	20·4
Beech Forest	66·37	9·5	14.4

Statistical determinations, however, while conveying important information in regard to the relations between plants and climate, do not convey all the variations that affect the distribution of plants, particularly trees. While it is true that the variability in the Mallee is greater than in any other part of the State, and, therefore, the struggle to exist is increased, the intensity of that struggle can only be understood when the absolute variations themselves are considered. Thus, in the case of Northwest Victoria, as represented by Mildura, only a study of the records themselves will reveal how acute at times is the struggle to persist. The average for the 38 years of record is 10.94 inches. In the law of averages one naturally assumes that good and low rainfalls will alternate fairly regularly. In other words, it might be expected that rainfalls will occur as if they were selected at random. One is not prepared to find that eight successive years, 1895-1902, had rainfalls below the average, that is, that there were eight years of drought. The successive years, 1919-1927, were also all below the average. Under such conditions of life the average rainfall has very little meaning. It is the average of the successive lean years that has a real meaning. The average of the years 1895-1902 is only 7·91 inches. Again, it would not be expected from the law of averages that an extremely bad year would be followed by an almost equally bad year. Thus, in 1914, only 4·71 inches of rainfall were received, and, in the following, 6·77 inches fell. The two years together only produced a little more than the general average. The recurring periods of dry years suggests that the rainfall occurs in cycles, and that the year is not the correct unit to use. However, sufficient data have been given to show that the adversities against which plants have to struggle are extremely severe, and these adversities have an important bearing on the tree vegetation of the northwest of the State. It is of interest to note that the two most successful

trees, *Callitris glauca* and *Casuarina lepidophloia*, have very reduced leaves. The genus *Eucalyptus* is not equal to the task of producing a tree comparable in size to these two. This latter genus has, however, produced the peculiar "mallee roots," the large root stocks from which many shoots arise. These swollen root bases must be regarded as an adaptation to the environment.

Summing up, then, the influence of rainfall on the distribution of trees in Victoria, we may note that all three aspects have a very profound influence. The influence of the unfavourable conditions increases as the rainfall decreases in amount. The trees in low rainfall areas have to contend with unfavourable quantity, unfavourable distribution, and unfavourable reliability. All these aspects are expressed in the peculiar form of the eucalypt known as the mallee. On the other hand, where the tall timber grows, all three aspects are favourable and the forests assume a tropical appearance.

(b) EVAPORATION.

It is generally recognised that there is an intimate connection between the transpiration of the plant and the humidity of the air. Humidity is a very variable factor both from day to day and during the day itself. Humidity is not an absolute quantity in itself, but is only relative, and it therefore falls short as a measure of reaction by the plant to its environment. Relative humidity may convey wrong impressions. Thus, a given humidity at a given temperature does not have the same transpiration effect as the same humidity would have at another temperature. This fact is frequently lost sight of. Humidity, then, being only relative and not absolute, therefore requires the statement of some absolute quantity so that its connection with plant reaction can be studied. This is cumbersome and cannot be readily given effect to. Under the various aspects of rainfall considered, averages of absolute quantities were used, but no such averages can be obtained for humidity. Livingston and Shreve (4) have very aptly summed up the position in regard to Relative Humidity in the following words: "This (i.e., Relative Humidity) bears no quantitative relation to atmospheric evaporation, even with wind and barometic effects left out of consideration, for it is obvious that air with a given relative humidity must be more effective in promoting evaporation at a higher temperature than at a lower." Further on, the same authors say: ". . . . it is simply a mathematical abstraction and its value to agriculture or ecology will have to be determined by direct empiricism." Relative humidity as a means of ecological investigation must be considered a very imperfect instrument.

This meteorological quantity has therefore been discarded in favour of evaporation, which is a more effective measure of the reaction of the plant to the amount of moisture present in the atmosphere. Evaporation is an absolute quantity, being the

amount of water lost from a free water surface. The quantity of water lost by evaporation is a cumulative effect of the vapour pressures of the air and the temperature. As these two vary, so does the evaporation. The vapour pressure of the air is again the result of other factors, one of which is rainfall itself. It is perfectly obvious that the more rain that falls the more humid must be the air, and therefore the less must be the evaporation. In other words, rainfall and evaporation will vary inversely, but this does not hold always absolutely, because the distribution of the rain throughout the year is not uniform. Various types of distribution have been shown in Fig. 2. Unfortunately, evaporation data are very meagre, and therefore any detailed discussion of this factor is impossible. Evaporation, being measured from a free water surface in inches, is therefore readily comparable with rainfall. It may be regarded as axiomatic that the more the evaporation exceeds the rainfall the more xerophytic will the resulting vegetation be. Melbourne has a rainfall of 25·58 inches, but the evaporation from a free water surface is 38·77. For the six warmer months of the year evaporation exceeds rainfall, and therefore the vegetation is xerophytic. Evaporation is not the same as transpiration from the plant, and it has been shown by various workers on transpiration—e.g., Knight—that maximum water losses from the plant and from a water surface do not always coincide, but they do occur in the same period of the day. Those causes which accelerate transpiration accelerate evaporation, and therefore evaporation is a good measure of the influences to which the plant is subject. In our most xerophytic areas evaporation exceeds rainfall for the greater part or for the whole of the year, as, for instance, Coolgardie, with a rainfall of 10·07 inches, where the rainfall falls below the evaporation for every month of the year. In the northwest of Victoria evaporation exceeds rainfall for every month of the year except one. It has already been noted that here the eucalypts have the peculiar habit known as mallees (Plate XVII.B). While evaporation data are somewhat meagre for this State as a whole, it is entirely absent when we consider the heavier rainfall areas of the State. Data are lacking in other countries besides our own, and many formulae have been suggested (12) for obtaining the required information. Since evaporation is the direct result of varying humidities and temperatures, a simple relation ought to exist between all these quantities. Humidity, as ordinarily given, is a relative quantity, and is a function of temperature. If the relative humidity and the temperature be known, then the actual humid condition of the air can be readily ascertained. This relationship has been availed of in these studies, and, in the light of this, existing evaporation data have been examined. From these examinations the following formula—

$$e = 0 8 d$$

has been derived, where e = evaporation in inches of water and d = deficiency of vapour pressure in mm. of mercury. The closeness of the calculated evaporations to those actually found (13) is given for the capital cities in Table III.

TABLE III.—EVAPORATION DATA FOR THE CAPITAL CITIES.

Station	Average Evaporation	Calculated Evaporation $e=0\ 8d$	Percentage Difference
Hobart	32·10	30.81	4·0
Sydney	38·43	38·08	0 9
Melbourne	38·90	42·34	8·8
Brisbane	53·37	54·96	2 9
Adelaide	54·55	65 90	20 7
Perth	65·80	55·40	15 8

The first four calculated results are reasonably close to the observed data. In the last two, however, there are fairly wide divergences. There appear to be discrepancies in the data given. Thus, both Perth and Adelaide have approximately the same mean annual temperature, but, while Perth has a higher mean humidity, it has also a higher evaporation. This high humidity and high evaporation do not appear to be consistent.

Data on which calculations may be based for other places are also very meagre, and therefore only a few stations with calculated evaporations are given in Table IV. In this latter table are given stations from other States as well as from Victoria.

TABLE IV.—EVAPORATION DATA FOR SELECTED STATIONS.

Station	Rainfall	Evaporation	Months when rainfall exceeds evaporation
Kalgoorlie *a.*	9·27	87·74	0
Wentworth *a*	11·50	62 21	1
Werribee *a.*	19 66	45.74	2
Adelaide *a.*	21·08	54·29	4
Rutherglen *a.*	22·29	50·82	4
Melbourne *a*	25·58	38·38	6
Hobart *a.*	23 57	32·38	6
Beechworth *c.*	34·66	52·70	5
Cape Otway *c.*	33·79	35·17	6
Wilson's Promontory *c.*	40·73	24 32	10

a=actual average. *c*=calculated average.

Table IV. shows that with increasing rainfall there is a decreasing evaporation, and it has been calculated that evaporation

equals the rainfall when the annual totals are about 36 inches (13). The evaporation is intimately associated with temperature, but nevertheless it does represent a condition against which the trees have to contend.

The station Wentworth represents the conditions existing in the Mallee. Here the eucalypts have only partly succeeded, and. although they are numerically superior in point of individuals, they are not successful on the better soils. The stations Werribee and Rutherglen probably represent the conditions under which *E. hemiphloia, E. polyanthemos, E. melliodora, E. sideroxylon,* and *E. leucoxylon* grow. These species seek the drier portions of the State, and are therefore to be considered among the most thrifty trees we have. Trees whose timber is of such high technical value, and which can grow under such high evaporation conditions, are of the greatest importance to the State.

The conditions as they occur at Melbourne represent the commencement or the lower limit suitable for the widespread Messmate-Peppermint association, and the White Gum-Bracken association. The chief interest lies in Wilson's Promontory, where the rainfall is 40 inches. Only two months have evaporation greater than rainfall. In the still wetter areas it is more than probable that in all months of the year, on the average, rainfall exceeds evaporation. In certain years the actual evaporation is greater than the rainfall for some of the summer months, and then dry conditions exist, and in those years bush fires are frequent. That the evaporation is generally less than the rainfall is shown by the luxuriant growth of the fern gullies. The plants of this association love a humid atmosphere and a humid soil. It is under these conditions that *E. regnans* reaches its greatest development. This is one of the world's most remarkable trees, and, as it is restricted to these humid areas, every protection should be given to the forests in which it occurs.

(c) Temperature.

Evaporation is controlled largely by temperature, and therefore it is natural to find that where temperatures are highest evaporation is greatest. At Mildura, the record temperature, 123·5 degrees, has been obtained for the State. At this station the month of January has always had maximum temperatures of 100 degrees and over since records began. In the period of the record the maximum temperature for January reached or exceeded 110 degrees F. sixteen times. For February the maximum has exceeded 100 degrees twenty-seven times. December has always had a maximum of over 100 degrees. There are no records of continuous high temperatures, but at Wentworth, which is situated a few miles away, there have been during February nine consecutive days with a temperature of 100 de-

grees or over. Under such conditions it is not surprising that tree growth is very restricted. Nevertheless, forest is not unattainable, for *Callitris glauca* and *Casuarina lepidophloia* form reasonably good forests. It is interesting to note that this is one of the few places where the genus Eucalyptus is not supreme, and it is interesting also to note that all the three genera, *Eucalyptus, Casuarina,* and *Callitris,* are co-extensive throughout Australia. The upper extremes of temperature, coupled with low rainfall and high evaporation, are unfavourable to the development of the eucalypts. But, besides this inhibiting power, we have another marked effect of temperature. The species *E. rostrata* is the most widespread of all the species of the eucalypts. It extends to all States except Tasmania, where, indeed, no other red-wooded species extends, although there are several red-wooded species in Victoria. This species is essentially riparian (Plate XVIII.A), but is also found extensively in seasonal swamps, or in areas where the water table is not far below the surface. It is not a true riparian species, since the levels of our rivers vary enormously. On the flats and along the billabongs associated with the rivers, *E. rostrata* is found abundantly. When the river overflows all the trees live under swamp conditions. The water may remain for months and the trees are unaffected. During summer, when the rivers are very low, or even cease to run, even the riparian individuals are living under conditions of drought. Red Gum may be regarded as an indicator of wet conditions during at least some time of the year. This tree lines all the rivers of the Murray basin, where the streams open out on the plains. It does not occur on the plains if these are permanently deficient in abundant supplies of water. *E. rostrata* is found right along the northern plains themselves, then it sweeps southwards at the western end of the State, and comes eastward spasmodically along the basalt plains to Melbourne, and slightly beyond. In many of these southern areas it is found associated with the swamp gum, *E. ovata,* which does not occur either along the streams or on the plains of the northern or northwestern portions of the State. The swamp gum passes beyond Melbourne, and it extends both northerly and easterly. *E. ovata* passes right upwards into the mountains, into the regions of heaviest rainfalls, and occurs on varying elevations and soils. It occurs right throughout the mountain block in the centre and northeast of the State, but, besides this, it occurs also on the plains of that area. Wherever drainage is bad this species is found. It passes down into Tasmania. The two species, *E. ovata* and *E. rostrata,* meet at many points, and are intermixed at many places, but *E. rostrata* ceases as soon as the country rises sharply and the valleys begin to narrow. It follows up the Goulburn River along the river flats until they cease to exist. It occurs a few miles from the Alps to the east of Mansfield, and on the north follows the Mitta Mitta River nearly down to Mitta Mitta, but

here, as elsewhere, it fails to enter the mountains, although it is attacking them, so to speak, in a hundred places. *E. ovata,* on the other hand, although very widespread throughout the mountain area, and spreading out on the southern plains and down to Tasmania, yet never follows out in a northerly direction. The controlling factor is temperature. No isotherm fits the distribution of these two trees exactly, but it is somewhere between the 55 degrees and the 60 degrees isotherms. The mean annual wet bulb isotherm, 50 degrees, excludes *E. rostrata.* The wet bulb isotherm seems to agree with the distribution of the flora generally better than those of the dry bulb. *E. rostrata* avoids the low temperature areas of the State, and *E. ovata* avoids those with high temperatures. As both these species are controlled in their distribution by soil water, they are therefore independent of rainfall, and they may occur on any kind of soil. Red gum occurs on sands, basalt clays, alluvium, granite soils, and shales. The boundary lines of these species also mark the limits of other species, but these latter are controlled by other factors. Thus, for instance, within the boundaries of *E. ovata, E. regnans* occurs, but this latter species is not governed by temperature. Within the limits of *E. ovata* is to be found all the rainfall over 30 inches. Other widespread species within the limits of swamp gum are *E. capitellata, E. goniocalyx, E. Stuartiana* and *E. obliqua.* Within the limits of *E. rostrata* is found *E. hemiphloia.*

(d) Ocean Currents.

In the extreme east of the State the bloodwood, *E. corymbosa,* just crosses the border, and only extends for a few miles. It is essentially a tropical or sub-tropical species that reaches Victoria by means of the coastal lands of New South Wales. It extends right up into Queensland, and is even found in Central Australia. This species is not the only one that reaches Victoria, for there are a large number of others that reach eastern Victoria, from the north, but extend no further. Taylor (9) has included this part of Victoria with Tasmania in his vegetation map. Superficially this appears to be the case, but none of the very special tree species occurring here reach Tasmania. Ecologically, Tasmania is connected with the three heavy rainfall areas, South Gippsland, Otway, and the Warburton-Healesville area, but not with eastern Victoria. Ecologically, this region is not connected with any other part of Victoria. Its flora is very distinctive. Besides *E. corymbosa,* there are a number of other species of Myrtaceae that occur here, but nowhere else in the State, nor in Tasmania. Thus, among the Myrtaceae we find *Angophora intermedia, Melaleuca armillaris, Eugenia Smithii, Tristania conferta,* and *Eucalyptus botryoides.* The first two have a very restricted range. *Eugenia Smithii* extends westwards

to the Gippsland Lakes, which is the western limit of this tropical vegetation. All of these species of Myrtaceae extend to Queensland, but none occur in Tasmania. Other tree species found here are: *Brachychiton populneus, Eucryphia Moorei, Acronychia laevis, Elaeocarpus holopetalus, E. reticulatus*, and *Banksia serrata*. The Illawarra Palm, *Livistona australis*, occurs as an isolated patch near Orbost. This also extends to Queensland, but not to Tasmania. Besides these tree species, there are many other plants occurring here not found elsewhere in Victoria nor in Tasmania. In the so-called jungles of this area there is a much greater number of lianes than occurs in the much heavier rainfall areas of other parts of the State, particularly where *E. regnans* grows. In these latter areas there are only three climbers, but in East Gippsland there is a comparatively large number. The mostly tropical family Asclepiadaceae, which is not represented in the Tasmanian-Victorian heavy rainfall vegetation, is here represented by three species. The family Menispermaceae, which is tropical and warm temperate, has two species here. The following list shows the climbers that are represented here, but which do not occur in other parts of Victoria, nor in Tasmania.

Family	Species	Remarks
Menispermaceae -	Sarcopetalum Harveyanum -	Extends to Queensland
,, -	Stephania hernandifolia -	,, ,, ,,
Asclepiadaceae -	Tylophora barbata -	,, ,, N. S. Wales.
,, -	Marsdenia flavescens -	,, ,, Queensland
-	Marsdenia rostrata -	,, ,, ,,
Vitaceae -	Vitis hypoglauca -	,, ,, ,,
Passifloraceae -	Passiflora cinnabarina -	,, ,, N. S. Wales.
Liliaceae -	Smilax australis -	,, ,, Queensland
,, -	Rhipogonum album -	,, ,, ,,
,, -	Eustrephus latifolius -	,, ,, ,,
,, -	Geitonoplesium cymosum -	,, ,, ,,

It is remarkable that these do not occur in the heavy rainfall areas where conditions of growth are much more favourable. These latter areas are very distinctly rain forests. Their distribution is therefore not one of rainfall.

This East Gippsland province is a meeting ground of two floras. In it are found many eucalypts, which reach their best development in drier and hotter areas. *E. sideroxylon*, red ironbark, is found in many parts of the east, but nowhere in extensive pure forests as occur at Chiltern and the Bendigo area. The red box, *E. polyanthemos*, is very widely distributed in the east, but it is not so big a tree here as in the drier parts. These

species are a reflection of a somewhat dry or warm climate, although in places here they may be found about the 40 inch isohyet. These trees are getting out of their range. Nevertheless, they represent a degree of warmth and a certain degree of dryness. On the other hand, the tropical climbers and trees represent a degree of wetness and absence of cold. Their absence from the big timber areas is due to their antagonism to the wet cold winter. This area, then, in reality represents a meeting of tropical rain flora with a dry sclerophyllous flora. These climatic conditions are due to the warm ocean current that travels down southwards along the coast of New South Wales. This current has its origin in the warmer parts of the Pacific Ocean, and moves westerly until it meets the Australian coast, when it turns southward. At the southeastern corner of Australia it passes out into the Tasman Sea. This ocean current has been mentioned by Taylor (15), but he does not consider its influence amounts to much. While the meteorological data do not show that this area has any marked peculiarity, the abundant presence of tropical species indicates that there are, indeed, distinct features as compared with the climate of the areas to the immediate west. The sudden termination of this flora in a westerly direction is due to the presence of cold ocean current which travels easterly along the south coast of Australia. Its influence extends to about Wilson's Promontory.

(e) Wind.

It does not appear as if wind, apart from its general influence on other factors of climate, has had any direct influence on the distribution of species. The prevailing wind is southwest and the next common is northwest. South Australia has species which are not found in Victoria, notable among which is *E. cosmophylla.* This lies in the path of the wind, but it has not crossed the border. *E. diversifolia* is a south coast species extending from Western Australia and occurring also on Kangaroo Island. This just crosses the border, coming along the coast as far as Portland, but not extending far inland. It is quite possible that its distribution eastwards is due to wind. It is probable that its easterly movement has not yet finished, but the distribution of a eucalypt by wind is a very slow process, since the seeds are not winged, and there is no provision for the distribution of the fruits. *Eucalyptus,* like many other genera of Myrtaceae, *Callistemon, Melaleuca,* etc., has hard woody fruits which do not readily shed their seed, but retain it for years. These fruits remain attached to the tree, still green, for years, and it is not until some accident happens that the seed is shed. The copious reproduction of eucalypts after a fire or after a clear felling is thus accounted for. But this, while giving a good reproduction, distinctly lessens the time of spread. No other species appears to have been affected

in its distribution by wind except, perhaps, *E. Behriana.* This is a mallee fairly widely distributed in the northwest of the State, but it also occurs as an isolated patch to the north of Bacchus Marsh, where the rainfall is below 20 inches. Between this area and the northwest the country is forested, and the rainfall rises to 40 inches. Its presence in this spot, unfavourable to the surrounding trees, is evidently due to the commonly occurring northwest wind blowing seed on to the area. It may be that wind has also played an important part in the distribution of the other species, but that cannot be shown. It is a curious fact that all species have found the areas, no matter how separated, suitable for their needs. It would appear as if seed is distributed accidentally in a very widespread manner over a very wide range, and each species in time finds those habitats which suit it.

B.—Geological.

It is not surprising that so far in ecological discussions geology has only occupied a subordinate place. Climatic data are readily available. Moreover, everyone is more or less directly interested in climate, for it affects our daily lives and interests. Climatic data are easily understood, and, therefore, the importance that has been attached to climate in the distribution of plants is quite natural. Soil has, indeed, been recognised as a factor, but only comparatively slight importance has been attached to it. Thus Schimper (5) says: "Soil merely picks out and blends." Others, also, have considered it of very little importance. Hutchinson (2) makes the following statement: "The original composition of the soil is seldom a limiting factor, at least in so far as the forests of Ontario are concerned." On the other hand, Stamp (14) says: "Everywhere to the trained eye, geology—and the resultant soils—is seen to be the controlling factor on the local distribution both of forest types and of individual species." In Victoria geology plays a most important part in the distribution of plants. The geology of an area can very frequently be easily discovered from the distribution of the trees on that area. The line of demarcation is frequently very sharp, as is seen in the case of the basalt plains. These, in the main, are devoid of timber, but wherever any other geological formation outcrops in the basalt, there trees are found. It is exceedingly common to find trees, growing on the Silurian shales and sandstones, ceasing as soon as the contact with the basalt is reached. The majority of the forest areas in this State occur on the formations of the oldest of the three geologic periods. These three groups—Palaeozoic, Mesozoic, and Cainozoic—are all well marked in the distribution of trees in this State. Although each of these groups contains geological systems, these separate systems do not have, generally speaking, separate influences on the distribution of the tree species. The origin of the rocks

causes them to fall into the two well recognized classes—Igneous and Sedimentary. Both the Palaeozoic and the Cainozoic contain each of these two classes, but the Mesozoic, which is of very limited occurrence, contains only the one class—Sedimentary. So far as the distribution of the trees is concerned the rocks may be considered as consisting of the following five classes (Plate XIV.):—

PALAEOZOIC—	Sedimentary.
	Igneous.
MESOZOIC—	Jurassic Mudstone.
CAINOZOIC—	Sedimentary.
	Igneous.

In the Palaeozoic sediments several systems are represented, but the Silurian and the Ordovician are the most widespread. Generally speaking, the Palaeozoic sediments affect distribution similarly, but the Carboniferous at Mansfield is a marked exception. This differs greatly from the others in that the strata are not folded, but are gently inclined. The soil is rich and there is an absence of infertile rocky subsoil. This area is sparsely covered with red gum, *E. rostrata,* giving it a park-like appearance. The other systems of the Palaeozoic group consist of shales or sandstones, or both, which yield very poor soils. These are highly folded, faulted, and broken, and in these the roots do not find either abundant water, mineral nutrients, or, at times, even good foothold. The soil is frequently very thin (Plate XV.A), and this adds appreciably to the difficulties of the trees growing on them. It is only rarely, and then only on favoured slopes in the high rainfall areas, that the best type of high forest is found on these formations. On the contrary, very poor species of trees, as far as timber is concerned, are found on them, even in very high rainfall areas. Thus, at times, *E. cinerea* var. *multiflora, E. dives,* and *E. elaeophora* occur together. This combination, which is rarely found, indicates very poor soil conditions. On the ranges at Wood's Point, in the 60-inch rainfall area, both *E. elaeophora* and *E. dives* occur. South of Mitta township, also in the heavy rainfall area, *E. elaeophora* occurs sparingly on the ridges. This tree is really a tree of low rainfall areas. It occurs at Arapiles, where the rainfall is below 20 inches. It is found at all intermediate rainfalls. Its presence, particularly when associated with either *E. dives* or with *E. cinerea,* or both, is indicative of almost the worst possible soil conditions. These trees are independent of rainfall, and their presence indicates that they are merely occupying areas too unfavourable for better timber species. These Palaeozoic sediments are always tree-covered, even in low rainfall areas, mainly with the rough-barked species, *E. amygdalina, E. obliqua, E. macrorrhyncha, E. capitellata, E. polyanthemos,* and *E. sideroxylon.* Besides these, however, there are a large number of others. At Inglewood and

Wedderburn, where the rainfall is below 20 inches, the mallees intrude on to these sediments. This is most unusual.

The igneous rocks of the Palaeozoic group provide the finest forests we possess. Some of the soil is highly fertile, but on the whole these areas have not been successfully used for settlement. These igneous rocks all possess the same general chemical composition, but physically they may be somewhat widely different. Their widely differing physical constitutions naturally result in widely differing soils. These igneous rocks, which are widely scattered in the State, are grouped into three sections according to their crystalline characters: the granite which is coarsely-crystalline, the porphyry in which large crystals occur set in a fine ground-mass, and the dacite which is finely-crystalline. The term granite is used here in a wide sense, covering all acid, coarsely-crystalline rocks. The first two occur over a wide range of rainfall, but the dacite is mainly confined to the heavier rainfall areas. Although these three classes of rocks produce different soils, they carry the same forest species where the rainfall is similar. These soils are all highly siliceous and are very favourable to tree growth. This is well illustrated on the basalt plains at Bulla. These plains are wholly or almost treeless, but wherever the granodiorite outcrops on the surface it is freely covered with grey box, *E. hemiphloia* (Fig. 3). The same state of affairs is seen in the same area where the

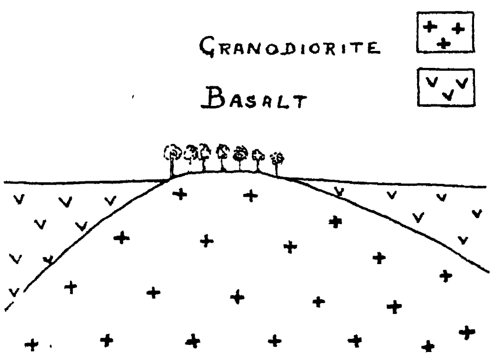

FIG. 3.—Trees covering the outcrop of Granodiorite but not growing upon the Basalt.

granodiorite has been exposed in the floors of the valleys carved out of the basalt plains. Here the trees occur, mainly red gum, *E. rostrata,* owing to the abundance of water present in the granite rocks. The red gum does not pass on to the basalt (Fig. 4).

In the large granite area to the south of Bendigo, red gum is found even high up on this formation. Red gums are essentially lovers of moisture, and this accounts for their being

found on river banks. Their presence on the granite suggests that there is abundant soil moisture present. Immediately to the north of this area the Ordovician shales carry a pure forest of red ironbark, *E. sideroxylon,* but this species does not come

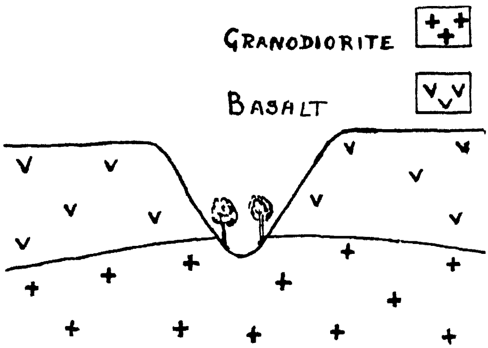

Fig. 4.—Red Gum (*E. rostrata*) growing in the valley where the Granodiorite is exposed.

on to the granite. The large granite outcrop at Maloga carries almost a pure forest of *Callitris glauca* and scattering grey box, *E. hemiphloia.* On the surrounding plains trees are very sparse, but the black box, *E. bicolor,* occurs along the streams. To the west of this granite outcrop is another at Buckrabanyule, where *E. hemiphloia* occurs scatteringly along with *Acacia implexa, Casuarina stricta,* and *Exocarpus cupressiformis.* This is the last outpost of the tree eucalypts. At Wycheproof, further north, where there is a small outcrop of granite, no eucalypts occur, but the other tree species are present (Plate XVI.A). Further north the mallee commences.

The Palaeozoic igneous rocks in the different rainfall zones are occupied by almost the whole range of the eucalypts. In the lower rainfall areas *E. polyanthemos,* red box, and its common associate red stringybark, *E. macrorrhyncha,* are quite common, as, for instance, on Morgan's Lookout, Glenrowan (Plate XVI.B). *E. elaeophora* also occurs here as well as elsewhere. In these drier areas all those trees which are found on the Palaeozoic sediments are found on the granite, with the very marked exception of red ironbark, *E. sideroxylon.* This is the more remarkable, since it prefers the dry, gravelly hill-tops of the Ordovician country. In the high rainfall areas *E. regnans* occurs as pure forest (Plate XV.B) on igneous rocks, but only scantily on the sediments. In these areas soil very materially affects the distribution, which is quite the reverse of the opinion of Russell (16). No soils are so responsive to tree growth as those derived from the Palaeozoic igneous rocks. In general it may be said

that these latter are true forest soils except those derived from dacite, which is very rich, but limited in amount. The granite soils are usually too poor for agriculture, although they make good grazing land. In the heavy rainfall areas, where this land has been cleared scrub and bracken fern have overrun it, and these plants have greatly increased the intensity of the fires that periodically ravage these parts of the State.

The Palaeozoic rocks are the most important forest areas the State possesses, and they must always be the chief source of our timber supplies. The woolly butt or red mountain ash, *E. gigantea,* is restricted to these rocks. Our chief forests of *E. regnans,* white mountain ash, occur on them. Besides these, a large number of other species reach their best development. as mountain grey gum, *E. goniocalyx*; candle bark, *E. rubida*; messmate, *E. obliqua*; brown stringy-bark, *E. capitellata*; peppermint, *E. amygdalina*; and red ironbark, *E. sideroxylon.* These rocks occupy some 30 per cent. of the State, but not all of this, however, is forested, for there are contained in it large upland areas which are only suited for grazing.

The Mesozoic rocks all occur on an east-west line in Southern Victoria (Plate XIV.). They probably were once continuous, but subsequent geological changes have isolated them into three areas—the South Gippsland, the Otway, and the Western District around Casterton. The first two of these were heavily forested, but they have been now almost completely opened for settlement. Settlement, however, has steadily failed, and these areas are rapidly becoming worthless waste land. The western area is below 500 feet in height. Settlement began here very early, and it is undoubted that it was the remarkable treelessness of this area, combined with the rich growth of grass, that attracted the Hentys to it in the 'thirties. Trees occur freely on the adjacent Tertiary plains, but they do not cross on to the Jurassic. Economically, the other two areas are really forest soils. The soil is undoubtedly rich and the rainfall abundant, but the successive failures that have attended settlement mark it out as forest land. In addition, too, there is the fact that these areas bear equally good forest as the Palaeozoic igneous rocks, and neither of these areas is very extensive. These rocks contain the same species of eucalypts as the Palaeozoic rocks of the high rainfall areas, with the marked exception of *E. gigantea.* The blue gum, *E. globulus,* is abundant in the southern parts, but almost absent in the igneous area. Although formerly carrying wonderful forests, to-day these Jurassic rocks are of very little value. The total area occupied by the Jurassic mudstones amounts to only a little over 2 per cent. of the State. Owing to their favourable conditions for tree growth, and the fact that they are largely waste lands, they form natural areas for reafforestation with suitable coniferous species.

The Cainozoic rocks are the most widespread, covering about 67 per cent. of the State. These areas are mostly at low elevation, and are therefore not sharply contoured. Very small areas of these lie in areas of high rainfall, and the bulk occurs in areas having rainfall below 30 inches. These areas are chiefly agricultural, comparatively little being forest land. Tree growth is entirely absent over wide areas of fertile soil, and in other parts typical savannah prevails. It is only in the eastern portion of the State that good high forest prevails on this Cainozoic formation. There are two distinct rock types in the Cainozoic, the Igneous or Basaltic, and the Sedimentary. On account of its treelessness the first of these may be said to be strongly antagonistic to trees. The sheoke, *Casuarina stricta,* forms small patches of pure forest on the basalt plains in parts, and this is the most successful tree occurring naturally. *E. rostrata* also forms pure colonies (Plate XVII.A) in parts, or mixed with *E. ovata,* swamp gum, but these trees are here large-crowned and short-boled. The second rock type produces grassland in parts, but more generally some form of woodland. The north-west or mallee contains, besides the various species of eucalypts forming mallee (Plate XVII.B), quite a large number of other species, most of which are not found elsewhere in Victoria. The cypress pine, *Callitris glauca,* which occurs abundantly at various parts along the valley of the River Murray, extending as far east as the Melbourne-Sydney Road, is plentifully found here, forming pure forest on the lighter soils. The belar, *Casuarina lepidophloia,* also forms pure forest or mixed forest with *Callitris glauca.* This species of *Casuarina* is exclusively restricted here. The needlewood, *Hakea leucoptera,* may also form small isolated pure colonies. Other tree species found, but never in abundance, are *Pittosporum phillyraeoides, Fusanus persicarius, F. acuminatus, Acacia homalophylla,* and *Heterodendron oleifolium.* In the southern parts of the State the sedimentary rocks are much better clothed with trees than in the northern. These southern parts are more sandy and this is more suitable for tree growth. The species of trees are mainly rough-barked eucalypts. The dunes just away from the seashore have a special tree vegetation which includes *Casuarina stricta, Banksia integrifolia, Acacia longifolia, Myoporum insulare* associated with *Leptospermum laevigatum.* In the east there is a very great variety of eucalypts, the species occurring on the Palaeozoic also occurring on the coastal plains. This area is distinctly forest land.

(a) Soil.

1. *Physical Constitution.*

Considerable attention has been paid to the physical constitution of the soil, but this has been chiefly on account of its agricultural importance. As yet, however, its importance in

ecology has not been recognized except casually. As a factor, however, in distribution it is just as important for some species as other factors are for other species. It cannot be too strongly stressed that there are a large number of factors affecting distribution, and that in the past ecologists have sought to relate distribution to too few factors rather than to seek explanations in new ones. It has been well recognised in agriculture that some soils are more suited for some crops than for others, but that fact has never been fully grasped by ecologists. It is probable that the influence of Schimper has clouded the outlook of investigators by insisting on the great influence of climate, particularly rainfall, and the minor importance of soil. In this State, however, soil is a most important factor, and just as important as any climatic influence. It may be said that, in general, the eucalypts favour sandy soils and loams and are not favourable to heavy soils. The tallest trees in the State are found on the lighter soils derived from igneous sources. On the basalt, where heavy soils are found, trees are entirely wanting over large areas.

The most outstanding case of the control of distribution by the physical constitution of the soil is seen in the case of *E. viminalis*, the white gum. This tree occurs in two well-marked varieties, *alba* and *arenaria*. The first variety, *alba*, is to be found in the valley floors or on the small alluvial flats of the heavy rainfall areas or along the streams from these areas. In such places, it frequently forms small pure forests, as may be seen on the Watts River at Fernshaw. This variety of *E. viminalis* never passes from the relatively lower elevations of the valley floors to the higher ground. In the valley floors, the hill wash and the detritus collect, and this holds the moisture, but is at the same time well drained, and in this *E. viminalis* finds its most favourable environment. On the sandy flats *E. viminalis* frequently forms a pure colony with *Pteridium aquilinum* as the only associate. These sandy flats and the floors of the gullies are comparable in that, while they are well watered and constantly moist, they are well drained and there is no free water present. The variety *alba* is essentially an inhabitant of relatively low elevations, but at Drouin and at Loch it occurs as very large trees on the crests of the ridges. The soil is rich and well watered, and the presence of *E. viminalis* here is indicative of the fact that there are other factors present which are inhibiting the usual mountain species. The presence of this variety in the Wombat Forest, where it extensively occurs, associated with *E. obliqua* and *E. amygdalina*, cannot at present be satisfactorily explained. These three species are frequently associated, either all together or any two of them, on various types of soil, but these are always well drained. The sandy soil is the habitat in which *E. viminalis* is commonly found, and it is frequently associated with these two rough-barked species. On the hill slopes, however, *E. viminalis*

does not occur. It is therefore probable that the Wombat Forest marks the meeting-place of two soil types. The basalt plains are normally destitute of trees, but at the Stony Rises, between Colac and Camperdown, the variety, *alba,* is found. As the name of the place implies, the plain is here broken into stony ridges and hollows. It is in these hollows that this variety is found. The basalt has not here weathered into the heavy black clayey soil that is usually the case. In the hollows this species finds among the stones those conditions of moisture and drainage that are favourable to its development.

The other variety, *arenaria,* occurs where the rainfall is lower and where the water supply is deficient during the summer months. Both varieties agree in this, however, that no matter what the rainfall may be, the soil must be well drained and generally very friable. It does not matter how damp the soil may be so long as it is well aerated. The soil must never be saturated. A common associate of this variety throughout its range is the common bracken fern, *Pteridium aquilinum.* These two species are indicative of a porous condition of the soil. Sandy soils which have borne this species of eucalypt, when cleared are commonly overrun with bracken if left uncultivated. *E. viminalis,* var. *arenaria,* is found right throughout the southern areas of the State wherever the coastal plains occur. This variety may be seen at Lakes Entrance, Inverloch, Port Phillip, Peterborough, Warrnambool, and Portland. The soils on these coastal plains are very sandy and have a low water-holding capacity. They are very loosely compacted and hence are both very well aerated and drained. They are underlain at varying depths with a very stiff clay whose distance from the surface determines whether trees or scrubs occur. Where trees do not occur, the flora of these sands is seen to be very xerophytic and consists of low scrubs, typical species being *Epacris impressa, Leucopogon virgatus, Banksia marginata, Leptospermum scoparium, L. myrsinoides, Acacia oxycedrus,* and *Casuarina distyla.* Thin stems and small pungent leaves are common. These sands are the commonest habitat of *E. viminalis,* var. *arenaria,* and the controlling factors appear to be the porosity of the soil and its well-drained condition. These conditions are normally not present on the basalt plains. There the soil is heavy and is not well drained owing to the flatness of the contour. Normally, *E. viminalis* is absent from these plains, but at Branxholme, where the basalt has broken down to an ironstone rubble, this species does occur. This gravelly soil, while it is chemically widely different from the sands of the coastal plains, yet physically is comparable to them in that it is well aerated and well drained. The basalt breaks down also into other types of soil, but *E. viminalis* is not found on them. If the soil be not porous then this species is absent.

Another remarkable occurrence of this variety on the basaltic formation is on the cinder cone at Mt. Franklin. This mountain

is an extinct breached crater of newer basaltic times. It is formed of scoria and cinders which are not greatly decomposed, although the surrounding basaltic plains consist of heavy black clayey soils. The cone therefore physically is comparable to the sands, and on it is found a number of trees which are commonly associated with *E. viminalis* on the sands, the tree species present being *Casuarina stricta, Banksia marginata* and *Exocarpus cupressiformis*. These trees are not restricted to the sands, but this association is very common there. These two occurrences of *E. viminalis* on the basalt are entirely due to the physical condition of the soil. Another remarkable occurrence of *E viminalis* var. *arenaria* is on the limestone soil at Buchan. This limestone country was evidently lightly timbered, as is often the case with *E. viminalis* country, and this undoubtedly accounts for its early settlement. The surrounding country which is heavily timbered has not been settled even yet. This surrounding area consists of quartz porphyry and carries a variety of rough-barked eucalypts, but *E. viminalis* is not found among them. Associated with *E. viminalis* on the limestone is *E. melliodora*. The soil, due to the abundance of lime, is friable, and this character makes it to a certain extent comparable to the sand, so far as its physical condition is concerned. As Russell (16) says, "Calcium carbonate may greatly modify the clay properties and give a considerable degree of friability to a soil which would otherwise be very intractable."

The physical constitution of the soil is also the controlling factor in the distribution of the red ironbark, *E. sideroxylon*. This species is quite comparable to *E. viminalis* in its desire for well drained soil conditions. Where it occurs at its best, the red ironbark is present where the ridges are capped with ironstone gravel, conditions under which *E. viminalis* might be expected to occur if more moisture were available. In the Bendigo district it forms pure forest at times, but at other times it is associated with grey box, *E. hemiphloia;* red box, *E. polyanthemos;* and red stringybark, *E. macrorrhyncha*. When it occurs as pure forest, it is probable that the most favourable conditions exist for its growth. It also occurs in the east of the State but never as pure forest. It mostly grows there on sandy soils where one would naturally expect to find *E. viminalis*. The optimum conditions of growth are never found in the east, but nevertheless it always occurs on well drained soil. The conditions there are on the borderland of the conditions of its environment.

While the physical condition of the soil has not only an important influence on the distribution of individual species, it also has a most profound influence on the distribution of vegetation itself. Schimper (5) has considered that the soil has only a minor influence on vegetation, believing that climate, particularly rainfall, is the determining factor. Schimper con-

sidered that an evenly distributed rainfall was the cause of grassland, and hence this type of climate was referred to as grassland climate. The metropolitan area of Melbourne has an almost even distribution of rainfall throughout the year, the two extremes of average monthly rainfall being 1·7 inches in February and 2·5 in October. However, grassland is not universally present throughout this area but is localized. This even distribution of rainfall extends easterly from Melbourne to the eastern boundary of the State and then it turns northwards. Instead of being grassland this area is mostly all forest. There is a large triangular area lying roughly in between Sale, Maffra and Traralgon which is plain country carrying *E. tereticornis.* This area was early settled, probably because it was well grassed and never densely timbered. In the metropolitan area there are in the main three geological formations present, each producing a characteristic soil: the Tertiary Sands, the Basalt Plains and the Silurian Sediments. The first produces a very sandy soil, the second and third produce clay soils. The sands are covered with trees or scrub or both, the Silurian with trees but very little scrub, while the basalt plains are grassland. Throughout the State, sandy soils are always covered with tree or scrub growth. Even the dunes near the sea shore are covered with such trees as *Leptospermum laevigatum, Casuarina stricta, Banksia marginata* and *Acacia longifolia.* Behind these again *E. viminalis* may be found. On the dunes in the Mallee where the rainfall is not much above 10 inches, trees such as *Casuarina lepidophloia* and *Callitris glauca* form reasonably good high forest. On the acid igneous rocks, as granodiorite, dacite and quartz porphyry, trees are always abundant. All of these rocks contain free silica, and hence the soil is more or less open according to the size of the silica particles present. It may be said that the lighter soils are generally suited for tree growth. It is on such soils that the tallest trees are found. On the other hand, wide areas of the heavier soils are frequently either destitute of trees or are only very sparsely timbered. Thus we find the basalt soils of the Western District quite treeless for miles. These soils contain a large percentage of clay and only a small percentage of sand. Different authors have used the term clay to define different sized particles. Howell (17) follows the American practice and uses the term clay for particles below a diameter of 0·005 mm., while the English authors, for instance Russell (16), use it for particles below 0·002 mm. In the accompanying table are given the mechanical analyses of typical soils from the treeless areas of the basalt soils. The analyses are by the Victorian Department of Agriculture.

It will be seen that all these soils are particularly lacking in sand, but all have a fairly high percentage of clay. The soils are practically made up of the finer materials, that is, with particles of a diameter less than 0·1 mm.

TABLE V.—SHOWING THE PERCENTAGES OF THE VARIOUS SOIL PARTICLES IN VICTORIAN BASALTIC SOILS.

Fraction	Size	Bungaree	Cressy	Tower Hill	Camperdown
Fine Gravel -	2–0·1 mm.	- 0·21°/₀	- 0·77°/₀	- 0·12°/₀	- 3 87°/₀
Coarse Sand -	1–0 5 mm.	- 2·45	- 3·04	- 0·76	- 4·23
Medium Sand -	0·5–0·25 mm	- 2·15	- 1·81	- 1·35	- 1·27
Fine Sand -	0·25–0·1 mm.	- 6·88	- 4·59	- 7 93	- 4 33
Very Fine Sand -	0 1–0 05 mm	- 22·99	- 27·19	- 9 46	- 18 56
Silt -	0 05–0 01 mm.	- 3·77	- 3·42	- 2·62	- 4 22
Fine Silt -	0 01–0 005 mm	- 16.58	- 6·46	- 6·70	- 9·61
Clay -	Below 0 005 mm.	- 33 59	- 34·84	- 40 75	- 31 75

It is the physical composition of the soil that is, in a great measure, responsible for the occurrence of grassland or woodland. In this State, both formations occur in the two types of rainfall, the so-called winter and the even distribution. Wherever there is a high percentage of clay or clay and silt in the soil, grassland will result. In the Wimmera, which is not basaltic, grassland occurs. Here the percentage of finer materials is 57·34 per cent. Clay has a marked power of swelling when wet, and of contracting and opening into deep cracks when dry. In the plains the clay soils swell on the surface when wet, and do not permit the ready entrance of water. Percolation is very slow and the soil bcomes saturated. Aeration is bad and plants possessing deep roots find it difficult to establish themselves. In summer, the open cracks, extending it may be for several inches into the ground, permit of very serious loss of soil moisture. It has been suggested that the even distribution of rain is necessary for grassland on account of the shallowness of the root system. Grasses, however, do not necessarily have shallow roots, nor do they necessarily have a very fibrous system. Grasses such as the native species, *Poa caespitosa, Chloris truncata, Stipa semibarbata, Danthonia penicillata*, etc., do have restricted root systems and are very fibrous, but other grasses, such as *Spinifex hirsutus*, which is an inhabitant of sand dunes and has to seek a long way for its water requirements, have very few roots, but they are very long. The habitat in a very great measure controls the type of root development. A shallow fibrous-rooted plant would stand very little chance of persisting on a sand dune even with an evenly distributed rainfall. Sandy soils are very permeable to water, and it is for this reason that tree development has occurred in the Mallee. The sand ridges so called are not pure sand, as chemical analysis shows. They are wind-blown material of the nature of loess, but mechanically they have the properties of sandy soils. Howell (17) shows that the red soils of the Mallee have a very high percentage of granular material above 0·05 mm. diameter. The average percentage in the three

samples given by him was 59·466. These dunes are tree-covered, although the rainfall is not so very far from being uniform. In the western portions of the State, west of the Grampians and thence southwards, the Tertiary plain is partly red gum flats and partly sandy areas, with *E. viminalis* and *E. capitellata* associated with *Xanthorrhoea minor*. The presence of the red gum is indicative of abundance of water. In the east of the State, in the large triangular area lying between Sale, Traralgon and Maffra, red gum areas again occur. The species of the red gum here is *E. tereticornis*. Here again are found sandy areas covered, not with red gum, but with a large variety of rough-barked eucalypts, as *E. eugenioides*, white stringybark; *E. viminalis*, white gum; *E. cinerea*, mealy stringybark; and *E. Stuartiana*. In both of these areas the sandy patches are always tree covered. Warner (1) has shown that sandy soil in the midst of prairie is covered with forest and he remarks, "This disjunct area is an example of a pure forest being retained west of its climatic range by edaphic conditions." Sandy soils by their looseness and lack of cohesion and of any colloidal property freely admit the rain water which passes readily down into the soil under the influence of gravity. The looseness of the soil acts as a mulch, preventing evaporation. Trees can readily grow and send their roots down.

The clay soil, on the other hand, does not admit free entry of water which, when it does enter, does not easily pass into lower levels.

The higher the percentage of clay in a soil the nearer does the water holding capacity of the soil approach the saturation value. The basalt soils all contain a high percentage of clay. The average of four analyses made by the Victorian Department of Agriculture was 35·23 per cent. of clay (i.e., particles of a diameter below 0·005 mm.). The upper and lower limits were 40·75 and 31·75 respectively. The average for the four samples of material below 0·05 mm. diameter (i.e., clay, fine silt and silt) was 48·58 per cent. It is the large percentage of clay in a soil that determines to a very large extent whether the vegetation shall be woodland or grassland. While the soils themselves are very slowly permeable to water, the subsoils are even more so, and this greatly impedes the percolation of water and the penetration of roots. Clay soils are essentially grasslands, while sandy soils are essentially forest lands. Fletcher (18) states that the soils of the prairies of U.S.A., while differing very widely chemically, are very similar physically. They all contain a very high percentage of silt and clay, thus possessing great tenacity. The silt ranges from 55 to 75 per cent. and the clay from 6 to 15 per cent. Warner (1) says that the prairie in Texas, which is not of glacial origin and which is typical of the southern prairie, contains a high percentage of silt and clay, the respective amounts being 49·1 and 30 per cent. by the American standard.

Schimper states that, on account of the fact that grasses are shallow-rooted plants, moisture in the subsoil has little influence on the covering of grass, and he goes on to say that a good grassland climate has frequent atmospheric precipitations during the vegetative season. In the tables of rainfall given by him under *Warm Temperate Grassland Climate* are cases where the conditions are very similar to those existing in Victoria. The climate of the pampas of South America is spoken of as a perfect grassland climate. In this, the winter rainfall—that is, from April to September—is greater than the summer fall. The ration is 1·3:1. Approximately similar conditions exist in Victoria, but the vegetation is not necessarily grassland. In the pampas climate, the heaviest average monthly rainfall is five times greater than the lowest. This is greater than in most cases in Victoria. Schimper notes that the climate of South-east Australia gives the impress of a good grassland climate, but he explains the absence of grassland on the view that the absence of dry periods during the spring months and the mildness of the winter are responsible for tree growth. There are widespread areas in the State which have a winter-summer ratio similar to those given by Schimper and where the rainfall is as evenly distributed, but woodland occurs, not grassland. In the north-west of the State, where the rainfall is only a little above 10 inches, the ratio of winter to summer rain is 1·5:1, while at Wood's Point the ratio is 1·7:1. As has already been remarked, there are no really great differences between the summer and winter rainfall. It has been stated in this paper that the rainfall of Victoria is really only a modified winter type. This is shown by the fact that the heaviest monthly fall for Wood's Point is 3·3 times heavier than lightest summer fall, and for Mildura 2·5 times. For the perfect grassland climate of the Savannah given by Schimper, the heaviest average monthly fall is five times greater than the lightest summer fall. So far as Victoria is concerned, the type of rainfall received has no effect in so far as woodland or grassland is concerned.

Clay soils are typically grazing or agricultural land, while sandy soils are true forest soils. Analyses given by Howell (17) and by the Department of Agriculture, Victoria, for soils in the plain country where grassland occurs, show that the percentage of clay and silt is very high. It is a significant fact that the sandy soils have been so little settled. These latter areas in many cases do not carry good forest, although the rainfall is sufficient for forest growth. The eucalypt is not a thrifty tree, but demands favourable conditions of growth. The members of the genus *Pinus* provide many examples of very thrifty trees, and it is to this genus in particular that we must look for species for making those areas that are at present valueless economically profitable. Forestry is the complement of agriculture in the

effective use of the soil, and while agriculture demands the better soils, forestry on the other hand makes use of the poorer.

2. *Chemical Composition.*

Just as is the case with the physical composition of the soil, there has been a difference of opinion regarding the influence that chemical composition exerts upon the vegetation of an area. So far as igneous rocks are concerned, in this State the large continuous areas forming mountain ranges all belong to the acid series of rocks. The basic rocks, such as basalt, occur only as sheets of lava. There are no ranges of these. Basalt does occur at high levels, as at Dargo High Plains, but there also it occurs as plains. Hence no comparisons can be drawn as to the respective influences of basic and of acid rocks. The acid series of rocks are represented very widely in the State by all three modes of consolidation of the original magma: plutonic, hypabyssal, and volcanic. These three, although chemically identical, nevertheless produce different types of soil. The plutonic rock, granodiorite, weathers into its constituent crystals, quartz, biotite, and felspar, before they are decomposed. Biotite is very resistant to decay, as may be seen in any area where granodiorite is decomposing. The felspars become opaque as the rock disintegrates. These large constituents naturally give rise to a coarse soil. In the dacite, the constituent minerals occur as a very fine ground-mass in which are a few larger crystals. Mineralogically, the dacite is similar to the granodiorite, but, in some forms, hypersthene replaces biotite. The fine ground-mass readily decomposes into a fine, rich, chocolate loam. The soil is much more a loam than might be anticipated, owing to the high percentage of silica present, but this and the other crystals are exceedingly fine. The porphyry produces a soil intermediate between these two. Of the three types of acid igneous rock, two occur abundantly in the high rainfall areas of the State. These are clothed with some of the densest forests in the State. In these forests the mountain ash, *E. regnans,* is very abundant. This species is somewhat restricted in its range, but it occurs freely on three well-defined areas, all of which are enclosed by the 40 inch isohyet. In all these three areas the rainfall reaches 60 inches and over, but above 40 inches there is no difference in the vegetation. One area lies to the east and north-east of Melbourne, and this we may designate the Warburton. In this area, from north to south, this species, *E. regnans,* passes from Belgrave to Rubicon, and east to west from Walhalla to just north of Yan Yean. The other two areas are in the south of Victoria, the South Gippsland and the Otway. Physically, the soils are of different types. Very great differences exist between the soils derived from the two related rocks, dacite and granodiorite. Although these two rocks have been derived from the

same magma, and are chemically similar, physically they are widely different. The dacite weathers into a rich chocolate loam which is regarded as a first-class agricultural soil, but the rapid growth of scrub and bracken fern has militated against settlement. The granodiorite weathers to a coarse gravel which is very porous, and is not sought after for settlement.

The soils of the two southern localities are derived from the Jurassic mudstone, the origin of which is still uncertain. This rock contains the same minerals as the two igneous rocks just mentioned, but the crystals are not interlocked, as when formed from a molten magma, but are just mechanically thrown together. The constituents of the rocks are undoubtedly of volcanic origin, but they have been sorted by water. The resulting soil is rich, but the areas have not been successfully settled. Each of the three areas is comparable in so far as rainfall, physiography, and elevation are concerned, but other adjacent areas are equally comparable in these respects. These three areas are, however, closely related in the chemical composition of the rocks from which the soils are derived. Typical analyses (19, 20) of these three rock types are given in Table VI. An analysis of basalt (21) is given for comparison.

TABLE VI.—ANALYSES OF TYPICAL VICTORIAN ROCKS.

	Dacite	Granodiorite	Mudstone	Basalt
SiO_2	63·27	70 94	64·00	50·52
Al_2O_3	16·50	13·99	15 88	16·01
Fe_2O_3	0·68	0 35	1·90	1·40
FeO	5·10	3·02	3·86	8·98
MgO	2·48	0·8	1 81	6·13
CaO	4·18	2·35	2 02	8·05
Na_2O	2·36	3·94	3·42	3·08
K_2O	2·68	3·66	1 86	2·02
P_2O_5	0·15	Trace	—	0·39

It will be noted that the three related rocks have a high silica percentage, considerably higher than the basalt. A greater difference, however, exists in their content as regards iron, magnesium and calcium. These are all high in the basalt, but comparatively low in the three others. The alkalies are approximately the same for all. This applies also to alumina.

In the three chemically related areas, the tall eucalypt, *E. regnans,* is found right from valley floor to the crest of the ridge. Wherever the soils from these rocks occur in a rainfall of 40 inches or over, *E. regnans* occurs. These soils are its home. It forms extensive pure forests, and it is commonly associated with the hill tree-fern, *Alsophila australis.* It is in the

recesses of the mountains of these rocks that our magnificent fern gullies are developed. Adjoining these areas are Palaeozoic shales and sandstones enjoying the same climate, but it is only occasionally in sheltered spots that *E. regnans* is found on them. It is the limited occurrence of these Jurassic and igneous rocks that limits the widespread occurrence of *E. regnans.* These rocks occupy only a small percentage of the area receiving 40 inches and over of rain, but rainfall is only partly a controlling factor.

These three areas, Warburton, Otway, and South Gippsland, may be regarded as true forest land, owing partly to the wonderful forests (Plate XV.B) they produce, and also partly to the difficulty that has been experienced in attempting to settle them. Where settlement has been unfortunate, these areas have been devastated. These should be restored to what Nature intended them to be. Owing to the richness of the soil, abundant rainfall, moderate temperatures, and moderate contours, these areas, where devastated, present possibilities for introduced species, such as spruce, which demand very favourable conditions of growth. So much of these areas has been denuded of forest that natural reproduction is impossible, and planting is the only resource to re-establish forest conditions.

3. *Water Content.*

In discussing the physical constitution of the soil, it was mentioned that clay was an important cause of grassland. It is, however, not the only cause. In the west of the State, to the north and west of Casterton, there are patches of the sandy plain covered with savannah forest. The same occurs, as has already been mentioned, in the east in the Sale area. In both these cases the tree is a red gum, *E. rostrata* in the west, *E. tereticornis* in the east. These red gum areas alternate with loose sandy patches carrying various rough-barked eucalypts. The savannah forest is quite devoid of any scrub, although this is abundant on the adjoining sandy areas. These areas have long been settled on account of their pastures, and the trees have been largely removed. These pastures or grassland do not owe their origin to a high clay content, but to a high water content. Why these areas produce trees and grass instead of species of Cyperaceae and Juncaceae remains to be determined. It appears, however, that, although always moist, actual swamp conditions never arise. *E. rostrata* also appears in savannah formation on the basalt. This rock weathers into a stiff clay which has a high water-holding capacity. During the winter these soils are frequently saturated, and conditions of growth are very poor. Associated with *E. rostrata* on the basalt is the swamp gum, *E. ovata.* Neither of these ever produces good timber trees in such habitats. *E. rostrata* can withstand a greater degree of dryness than *E. ovata.* The former reaches its greatest development in the flats

associated with the main rivers (Plate XVIII.A). These areas are mostly subject to flooding, but they are also subject to extreme drought. It is the severity of these droughts which controls the distribution of *E. rostrata* in the north-west of the State. The heavy clay soils associated with many of the rivers, particularly the Wimmera, become very loose and broken under the prolonged heat and drought of summer, and these conditions become unfavourable for *E. rostrata.* Along the rivers in the north-west, *E. rostrata* is associated with *E. bicolor,* black box, but when conditions become extreme, *E. rostrata* fails to hold its own and only *E. bicolor* remains. Along the Murray both occur from about Echuca westwards. At Donald, both species are found, but a little further north at Birchip only *E. bicolor* remains. At Horsham and Dimboola, both occur. *E. bicolor* is essentially a tree of seasonal swamp land, and is never found in normal mallee formations.

In the range of these three species, *E. ovata, E. rostrata* and *E. bicolor,* there is a gradation of dryness of the environment from the first to the last. The first and last are never associated, but each is widely associated with *E. rostrata. E. ovata* is an inhabitant of areas that have a constantly moist soil. It never undergoes long or comparatively long periods of dryness. *E. rostrata* inhabits moist areas in the south and west of the State, but, in the northern plains, conditions are much drier. Here it reaches its best development. It meets *E. bicolor* a little to the east of Echuca. West of this conditions become more severe and *E. rostrata* ceases. They occur together at Kerang, but not at Pyramid. *E. ovata* is not a good timber tree, but the other two species are. These two must be regarded as among the most thrifty species we have, for they are inhabitants of areas which are of little value for other purposes, and which are also useless for other species of trees.

4. *Subsoil.*

The subsoil varies very widely as regards its depth from the surface, and this has often a profound influence on the vegetation. Beneath the Tertiary sands is an impervious clay overlain in most cases by an ironstone rubble. It is the distance of this impervious clay from the surface that determines whether trees or shrubs shall be the resulting vegetation. It is remarkable how the depth of this clay varies. When near the surface it may truly be described as a subsoil, but when this same layer is several feet down, it is rather stretching the term to call it subsoil. In this latter case, the true subsoil is usually more or less a pure sand. Nevertheless it is the impervious clay that is the determining factor, and hence it may be regarded as a subsoil. When near the surface and the drainage conditions are favourable for the free movement of water, scrub is the resulting

vegetation. The rain that gravitates to the impervious layer is lost to the local vegetation, for it drains away along the surface of the clay. Hence water supply during the summer months is very deficient. This scrub is markedly xerophytic, as is shown by the small, pungent, sclerophyllous leaves, thin stems, and stunted growth. The moisture in the soil is frequently very low, as is shown by the moisture analysis of this soil taken during a prolonged dry period.

TABLE VII.—PERCENTAGE OF MOISTURE IN THE SOIL DURING A DROUGHT.

Depth in inches		Moisture content
1	-	0·97%
6	-	1·25
12	-	1·07
18	-	1·27

It has been found by experiment that these percentages are far too low for germination. A soil with such a low percentage of water can only be inhabited by a very xerophytic flora.

Where the clay subsoil is far removed from the surface, water percolates to great depths, and hence trees can exist, for there is a supply for the roots. On such situations *E. viminalis* var. *arenaria* can exist either as pure forest or associated with bracken. It is also at times associated with *E. obliqua* and with *E. amygdalina,* as is seen at Nyora. It is these soils that are so opportune for afforestation with species of *Pinus*. Such soils occur in the Pine Barrens of North America.

If the clay be near the surface and the drainage conditions are imperfect so that the free water is not moved under the influence of gravity, then swamp conditions arise. Such a swamp may be seasonal or permanent. In the southern parts of the State in or around such swamps, either *E. rostrata* or *E. ovata,* or both, may be found. Grassland is often associated with the red gum, as is seen both in the east and in the west of the State.

(b) PHYSIOGRAPHY.

The central portion of Victoria consists mostly of a long range of old worn-down highlands, which extend from the Grampians in the west to the Alps in the east. These consist of a variety of rocks, including basalt. With the exception of the latter, this central core is well timbered, and may be considered forest land. The mountains of the east and north-east rise to sub-alpine heights, and consist also of a wide variety of rocks. This area is well watered and consequently contains good forest. Many factors within this area control the distribution of species. To

the north of the central axis are the plains which constitute part of the valley of the River Murray. These plains are mainly grassland, and form part of the wheat area of the State. They are only lightly watered, but they receive quite sufficient rain for the purposes to which they have been put. This is essentially an agricultural area. These northern plains are continued westwards as the Mallee and the Wimmera. The latter is essentially an agricultural area. The Mallee, as has been mentioned already, is agricultural so far as the climate will permit. There are areas unsuited either for forestry or for agriculture, which are locally known as deserts. Apart from these, the remaining land is agricultural, but it is a question of policy whether land carrying such good timber as belar, *Casuarina lepidophloia,* and cypress pine, *Callitris glauca,* should be opened for selection.

To the south of the central range is the great southern valley lying between the central range and the old Jurassic range. This valley, to the west of Port Phillip, has been filled by the basalt flows. This is treeless, except for patches of *Casuarina stricta.* In the west of these basalt plains, both *E. rostrata* and *E. ovata* are to be found associated. This area is typically agricultural. To the east of Port Phillip this valley has been variously timbered with species of *Eucalyptus,* but it has been mainly taken up for agricultural purposes for which it is most suited. Species occurring here are mainly peppermint, *E. amygdalina,* and messmate, *E. obliqua.*

The southern boundary of this valley has already been considered under the Chemical Composition of Rocks. These Jurassic ranges, with the exception of the Casterton, carried high forest of high quality, particularly forests of *E. regnans* and *E globulus.* Between the sea and the last range lie the coastal plains. Near the sea, the coast tea tree, *Leptospermum laevigatum,* forms pure forest over extensive areas, but associated with it are *Banksia integrifolia, Myoporum insulare, Casuarina stricta,* and *Acacia longifolia.* The commonest tree throughout this latter area is probably *E. viminalis* var. *arenaria.* In the west, *E. diversifolia* occurs for a short distance. *E. capitellata* is found both in the east and the west. It is in the east that a rich variety of species is found, and among others are found *E. Sieberiana, E. sideroxylon, E. polyanthemos, E. globulus, E. eugenioides, E. Stuartiana, E. Muelleriana.*

1. *Elevation.*

In the alpine area in the north-east of the State, the snow gum, *E. coriacea,* occurs abundantly at the higher elevations, but it does not cover all the peaks. This species attains a greater elevation than any other, and reaches timber line (Plate XVIII.B) at about 5,500 ft. Here it is reduced to a shrub, and is known as var. *alpina.* Compared with the Rocky Mountains, timber line

is reached at a much lower elevation. At a corresponding latitude in U.S.A. timber line is reached at about 11,500 ft. by *Picea Engelmanni.* So far as *E. coriacea* is concerned, elevation is not a controlling factor in its distribution, for it is found from sea level to alpine heights. Elevation excludes other species from the alpine area, and thus extensive pure colonies of *E. coriacea* occur. Below *E. coriacea* is found the red mountain ash or blackbutt, *E. gigantea.* Its upper limit appears to be about 4500 ft. and there it is succeeded by *E. coriacea.* While this latter species comes right down to sea level, *E. gigantea* does not pass below 3000 ft. It is thus a true sub-alpine species. This species is a tall tree, quite comparable in this respect to *E. regnans* (Plate XIX.A). Wherever rainfall and elevation combined permit, this species occurs. It is practically independent of soil, and in this respect differs materially from *E. regnans,* which is very particular as regards soil. *E. gigantea* is found just as freely on the Palaeozoic sedimentary rocks as on the igneous. Its range is therefore in some respects much more extensive than *E. regnans.* On Mt. Donnabuang and Mt. Arnold, *E. gigantea* succeeds *E. regnans,* but on Mt. Macedon and the Buffalo, *E. gigantea* occurs, but there is no occurrence of *E. regnans.* At Mt. Wellington, E. *gigantea* is abundant, but there is only a very small amount of *E. regnans.*

In the two southern localities where *E. regnans* is so abundant, South Gippsland and Otway, there is no *E. gigantea.* It has been noted already that these two areas are similar ecologically to the Warburton area, but neither of the southern areas rises to an elevation of 3000 ft. and hence *E. gigantea* is absent. In the Grampians the elevation of 3000 ft. is passed and the rainfall is also above 40 inches. The soil derived from the Carboniferous sandstone of which these mountains are formed is very poor in quality and only the xerophytic stringybarks are found.

The candlebark gum, *E. rubida,* is associated with *E. coriacea* in many places at fairly high elevations, as Dargo High Plains, Moroka River and Bendoc, but, like *E. coriacea,* there is no lower limit to its distribution. Both are found near Coldstream at low elevation. Neither of these trees appears to be controlled by elevation. In the case of *E. coriacea* it would appear that its formation of pure forest at high elevation is not due to the fact that it is specialized for such habitats, but rather that the conditions there, the accumulations of snow and the comparatively short summers, are too severe for other species.

E. gigantea is restricted both as regards upper and lower limits. It is undoubtedly adapted to the limits in which it grows. This species is remarkable for the purity of its forests. It does not usually associate with other species and form mixed forests. The very height of the tree, the density of its crown and the closeness with which they grow (Plate XIX.A) exclude

other species. In many respects it is comparable to *E. regnans*, which it meets at many points, but with which it does not intermix very much. The ground vegetation under *E. gigantea* is usually very scanty. This species is one of the most important we have. Apart from the fact that it produces an excellent timber of high quality, it grows at elevations where snow is fairly abundant through the winter. The dense canopy of the forest shades the snow and thus its melting is retarded and the water finds its way gradually to the streams. Every effort should be made to retain what is one of our greatest assets.

2. *Contour.*

It has already been stated that grassland is in a large measure controlled by the physical constitution of the soil. Clay soils possess many properties which prevent successful tree growth. Soil conditions, however, are greatly modified by the contour of the country. The Palaeozoic sediments, which are largely argillaceous, are worn down into highlands with fairly sharp contours in the high rainfall areas. In the lower rainfall areas they range down almost to plains. These clay soils of the highland areas are physically different from those of the basalt plains since there is never any free water lying on the surface. There is more run-off and less penetration. During the winter these hill soils are not saturated as in the plain country. On the hills the soils are usually shallow (Plate XV.A), but they never open out into cracks. They are generally more friable, due to the leaching out of the colloid constituents. Physically, then, we have an approach to the conditions existing in sandy areas which, as we have seen, are always tree- or at least scrub-covered.

These hills and mountains formed by the Palaeozoic rocks are always tree-covered, but the forests, owing to other factors, are exceedingly variable. Judged by the standard of the granodiorite and dacite they never reach Quality I. site. In the heavy rainfall areas *E. regnans* is found on the southern slopes in favoured localities. This species is found near Grant and also further south at Moroka Gap. It also occurs at Wood's Point. These, however, are rather isolated occurrences. No doubt many such other localities may be found, but they will never be extensive. In these regions of heavy rainfall, *E. obliqua* also reaches very large size, as may be seen near the old mining, but now uninhabited, town of Grant. In this same area are also exceedingly large specimens of *E. rubida*. But, although these fine specimens exist, exceedingly poor specimens of trees occur on these same soils within the same rainfall, as, for instance, *E. dives* and *E. elaeophora*. Not all of this mountainous area, although it receives moderate to heavy rainfall, is covered with forests

of any value. Some of it, indeed, as the Dargo and the Benni-son High Plains, does not carry any trees at all.

Between trees and plains there seems to be a certain amount of incompatibility. It has already been remarked that our plains are either mostly grassland or savannah. This State is not an exception in this respect, for the great grassland areas of the world are plains. The evenness of contour has as much to do, probably, with the distribution of grassland as the constitution of the soil itself. It will probably be found that the level surface of the earth accentuates those attributes of clay soils which make them unfavourable to tree growth. Mere elevation, without any surface relief, does not affect this apparent antagonism between plains and trees. In the alpine area there is an extensive plateau which bears mainly grass, of which the most common species is a variety of *Poa caespitosa.* These areas are just as devoid of trees over wide areas as the lowland plains. These upland pastures are covered with snow in winter, but in summer they provide excellent grazing. Although situated within what is a true forest region these plains are essentially agricultural and provide rich green pasturage at a time when the lowland areas are dry and parched with the heat of summer.

3. *Slope.*

In the slope of any area we are concerned with two effects, the angle of slope and the aspect. It is well recognized in the Northern Hemisphere that the slope facing the equator is always warmer and usually drier than the slope facing the pole. The equatorial slope naturally receives the rays at a much sharper angle—it may be at a right angle—than the outward slope. In this State, where the problem of water supply is constantly present, the southern aspect is always moister, and it is on these, as well as on the eastern slope, that the mountain ash, *E. regnans,* grows so abundantly. In the granodiorite-dacite areas the northerly and westerly slopes are covered with rough-barked eucalypts as *E. capitellata, E. obliqua, E. amygdalina,* and *E. Sieberiana.* These are associated with more or less xerophytic plants, as *Lomatia ilicifolia,* while *Lomatia Fraseri* is found only in the sheltered gullies along with *Nothofagus Cunninghamii.*

Another example of the effect of aspect on distribution is to be seen in the Mt. Wellington area. On the north slopes the heat-loving *E. polyanthemos* and *E. macrorrhyncha* are to be found associated with *E. Sieberiana.* On the cool, sheltered southern slopes, very fine specimens of both *E. globulus* and *E. goniocalyx* grow fairly abundantly.

C.—Biotic.

The two previous groups of factors, Climatic and Geological, do not explain all the facts of distribution. They do provide

us with information concerning the environment and the relationships of the plants to that environment, but there are problems of distribution of deeper significance which are not so easily explained. Under the biotic factors, as understood here, are included any phenomena related to life itself, no matter how manifested. Of particular interest is the problem of the discontinuous distribution of a number of species. It may be assumed that any particular species, e.g., *E. gigantea*, was once continuous, but geological forces or changes in secular climate have now broken that continuous occurrence into isolated groups. Under such conceptions we would assume that *E. gigantea* was once continuous throughout its range, but denudation has since carved out the valleys and worn down the highlands, leaving the several discontinuous groups on the mountain peaks as we now have them. East and west of the area where *E. gigantea* occurs, *E. sideroxylon* is found. Are we to assume, then, that the intervening area was once drier and now has become wetter? For every disconnected group certain changes would have to be invoked to explain such distribution. It seems more natural to assume that, as the various changes have occurred, new habitats have arisen, and that seed from various species has accidentally and continuously reached those areas. Those species most fitted for the particular habitat have survived. Willis (3) and others have shown that seed dispersed is not confined to those species which have special mechanisms for the distribution of their seed. Seeds are constantly being disseminated by some irregular means. The genus *Eucalyptus* has no special provision for the dispersal of its seed, yet its species always occurs in suitable habitats, no matter how remote. A striking example of this is the occurrence of *E. Behriana*, a mallee, in the isolated low rainfall area immediately to the north of Bacchus Marsh. Dispersal, then, is a problem connected with the plant itself, and through this dispersal each species is constantly finding those conditions which suit it.

(a) Fire.

In comparing comparable areas, one is struck by the fact that like areas are inhabited by like trees. The same fact may be stated by saying that similar habitats are occupied by similar associations. It is true that some trees, as, for instance, *E. globulus*, do not seem to follow any law as regards distribution, and the same applies to the snow gum, *E. coriacea*. These species appear at unexpected places. The latter has the capacity to withstand the cold and depth of winter snows at a little below 6000 ft. elevation and is the only tree species that can. We find this species, however, on the undulating Silurian country at Yering and on the Tertiary formation at Dandenong, only a little above sea level. It occurs on the dry Silurian shales at Eltham,

but it does not occur on the mountains to the north-east about Healesville. Very similar is the distribution of *E. globulus.* It occurs on the cool seaward face of the cliffs at Kalimna and comes down almost to the edge of the water. It is found on the dry northern slopes of the granite hills at Trawool, and, as a striking contrast to this, it occurs abundantly in the Otway Forest. These habitats do not appear to be related in any way. Such examples of distribution are unexplainable except on the assumption that these species are not specialized as regards habitat and will develop anywhere provided they are not crowded out by the local vegetation. Each of the areas where these two species are found, apart from the alpine home of *E. coriacea,* are typically habitats of other species or groups of species. The distribution of species of *Eucalyptus,* then, as well as species of other genera, shows that they occur in very definite areas and that the trees are in equilibrium with their environment. In other words, a climax condition exists, and therefore it follows that these areas have not been recently, or comparatively recently, subject to disturbing influences. Yet it is held by many, who have only a superficial knowledge, that fire has been an active agent in distribution and that the present associations are in a large measure the result of fire. If fire had been as intensive in its destructive power in the past as it has been since the advent of the white man we would surely find evidence of active succession, or at least a greater number of those curiosities of distribution that have just been discussed. But this is not so. It is maintained by supporters of the fire theory that evidence of adaptation is to be found in the protective defence of the rough, thick bark of the various eucalypts. Unfortunately for this theory, the thickest and most protective barks, e.g., *E. sideroxylon,* occur in areas where fires are infrequent and of no consequence. The thick-barked species are abundant in the lower rainfall areas. On the other hand, *E. regnans,* which occurs where fires are fiercest, has no protection as a young tree and only limited protection when old. In the areas with rainfall above 40 inches the forests are densest and the undergrowth greatest, and there is abundant material for fires. In the gullies of these heavy rainfall areas the vegetation may consist of several stories. With the exception of the tree ferns, none of the plants of these gullies is particularly adapted to resist fire. This is evidenced by the complete destruction that occurs (Plate XIX.B) when the fire is intensive. The amount of devastation and the intensity of the fire are closely related, and although it may be considered that this is axiomatic, yet the truth of it is frequently lost sight of.

In the secluded gullies where the several stories exist, the presence of large trees of such a sensitive species as *Nothofagus Cunninghamii* is surely evidence of the absence of fires over long

periods of time. The large root burls of the musk tree, *Olearia argophylla,* are indicative of extreme age. These burls are only found on very old trees. The common dogbush, *Cassinia aculeata,* is most frequently seen as a shrub, but in gullies where fire has been absent since the advent of the white man it may be found as a small tree, and even colonies of it are to be seen. All of these trees are readily destroyed by fire and their presence as large trees is evidence that fire has been absent. In the forest itself, away from the gullies, the occurrence of those huge giants of trees, as King Edward near the Cumberland, which was 88 ft. in girth six feet from the ground, Uncle Sam on the Black Spur, and many other famous trees of similar size both in this area, in the Dandenongs, South Gippsland and the Otway, is evidence of long continued immunity from fire. These trees have now all been destroyed and none remains, and this destruction has been wrought in the few short years of white settlement. Most old trees have hollow trunks, and this increases their possibility of destruction by fire. The age of these giants cannot be accurately determined, as the rings are so narrow and ill-defined. How slow growth may be is evidenced by King William Pine of Tasmania, *Athrotaxis selaginoides.* Rings in this species may be only four cells wide, and 50 rings to the inch is not an uncommon occurrence. In the case of *E. regnans,* both height and diameter growth are exceedingly fast in its early life (22). The rate of growth rapidly falls and at 80 to 100 years of age the rings of growth are no longer distinguishable. At a century old, in ordinary circumstances, the rate of growth is about 20 rings to the inch, and this rate steadily falls. The foliage on the old trees is not dense, and this is one of the causes of slow growth. From a study of the size of these trees and the decreasing rate of growth, it has been calculated that these big trees were the world's oldest living specimens. They were undoubtedly several thousand years old. Owing to their sensitivity, it is impossible to believe that these trees have endured centuries of fire. Since the advent of the white man, firing of the forest has shown that ultimately the forest area will be reduced to bracken fern. There is a retrogressive succession. The change may be rapid or it may be slow, and in the succession other plants, as *Cassinia aculeata,* may obtrude themselves; but ultimately the end point is the same, bracken fern. This plant exists spasmodically in the forest area. It cannot succeed where forests occur since it is strongly light-demanding. Its rhizome is unaffected by fire and in the re-growth after the fire the bracken fern rapidly makes its appearance. Its subsequent growth is largely a matter of how much of the crown canopy of the forest has been destroyed. Repeated firings open up the crown canopy more and more (Plate XX.A), thus giving the fern the necessary light. The large stores of food material in the rhizome give the bracken a great advantage over plants

which have to arise from seed. The latter are ultimately choked out when bracken is dense. When the white man first arrived the wide areas of bracken now seen did not exist, nor were there extensive areas of dead timber (Plate XIX.B). Fire is steadily changing the face of the forested areas.

(b) Virility.

The outstanding feature of the Victorian forests is the almost universal dominance of the genus *Eucalyptus,* particularly where conditions of growth are favourable. This dominance is exemplified in two ways, first, by the large number of species present, and, secondly, by the large numbers of individuals. The genus *Acacia* parallels *Eucalyptus* in the number of species, but only a comparatively few are trees and even these do not occur in large masses. The myall, *A. homalophylla,* is a tree in the Mallee, but this species of acacia is only spasmodic in its occurrence. The genera *Casuarina* and *Callitris,* both with winged seeds, are distributed all over Australia, but neither of these rivals *Eucalyptus* in species or in numbers of individuals. Both are comparable with *Eucalyptus* in the fact that both may form pure colonies to the exclusion of all other genera. Thus both *Casuarina stricta* and *C. Luehmannii* form pure forests in the grassland area and *Callitris glauca* in the north and north-west also forms forests to the complete exclusion of any species of *Eucalyptus.* At Beechworth (Plate XX.B), *Callitris calcarata* grows associated with several species of *Eucalyptus.* This latter condition is, however, rare. *Casuarina suberosa* is associated with many species of *Eucalyptus,* but is usually sparsely distributed and rarely in any quantity as in the Orbost area.

This virility has enabled it to colonize wide areas. As a colonizer it stands alone. It is probable that this power of exclusively inhabiting wide tracts of country is associated with its capacity to produce new species. The genus *Eucalyptus* is extraordinarily variable and this finds expression in the confused nomenclature of to-day.

(c) Age and Area.

Willis (3) in his Age and Area Hypothesis states that the area covered by any species is indicative of its age. This is undoubtedly true in general, but there are many obstacles in its application to any particular species or group of species. Willis himself recognizes that there are physical barriers in the path of a spread of a species from its point of origin, but there are, in addition to these recognized barriers, ecological barriers as well. The Age and Area Hypothesis implies rather a passive dispersal of species, but that is not the case. Thus *E. gigantea* is limited in its distribution by an insufficiency of elevated areas. There is no physical barrier to its spread, but there is an ecolo-

gical one. Again, *E. regnans* is comparatively restricted in its range owing to the fact that its distribution is controlled mainly by two factors, chemical composition of the rocks and high rainfall. It is only where both these factors are favourable that *E. regnans* is found. The Mallee vegetation is prevented from travelling south-east because conditions are wetter and cooler. The tropical species of East Gippsland do not come further west as the climate is colder. In none of these cases is there a physical barrier such as seas or mountain ranges impeding the spread of a species, but there are variations in the environment. The theory really fails to take account of such cases.

There are, however, cases in the State which do appear to come within the sphere of this hypothesis. In the south-west *E. diversiflora* has come east as far as Portland. There does not appear to be any ecological or physical barrier to its progress further east. Its present limits, then, may be regarded as due to insufficiency of time.

In the Grampians there is the very limited distribution of *E. alpina,* whose origin Maiden has discussed (23). There is no doubt that it is a derivative of the stringybarks, probably *E. capitellata.* Its very restricted range on the mountain peaks would suggest that its development has been very recent. Its birth may not be an expression of adaptation to its particular environment, which cases are contested by Willis, but its spread has certainly been prevented by lack of similar environments elsewhere. This species may, indeed, be very old. It may be neither a relict nor a newly-born species. It stands in a class by itself.

Other isolated species or varieties are the so-called *E. Cambagei* on Mt. Buffalo, *E. stricta* on Mt. Wellington, and *E. neglecta* at Omeo. There is, of course, the difficulty of deciding what constitutes a species. Many modern-day botanists seek every excuse to create new species and therefore it is often futile to discuss problems of distribution. *E. Cambagei* is not entitled to specific rank. It is undoubtedly a localized variation of *E. stellulata.* It has had its birth here and has not spread even yet across the Buffalo. This form is undoubtedly a case where its limited range is indicative of its age. There does not appear to be any reason at all why this form should not spread wherever its two associates, *E. coriacea* and *E. rubida,* occur together. The same may be said of the so-called *E. stricta* on Mt. Wellington. This is not deserving of specific rank. It is, however, a distinct variety of *E. coriacea,* very localized. It has all the appearance of a newly-formed variety which has not yet had time to spread. Here, again, there does not appear to be any barrier, ecological or physical, to its further distribution.

Trees as well as other plants differ widely in their relation to their environment. It has already been pointed out that some

species may be described as ecological wides since they are able to grow in a wide variety of habitats. Others, however, are restricted owing to their relationship to their environment being much more intimate. Hence no mathematical law of mechanical distribution could hold even when the species are very closely related, as *E. regnans* and *E. amygdalina*. The former is restricted by very definite ecological barriers, but the latter is very distributed and independent to a large extent of the environment.

Conclusion.

Of the three group factors discussed, the first two are the most important, namely, Climate and Geology. It may be said in general that these two are equally concerned in the distribution of trees. It is true that as we pass from high to low rainfall the height of the trees steadily diminishes, but that is only in general. Geological factors are so widespread that the effect of climate is being constantly modified, even almost obliterated. Thus in the highest rainfall areas of the State may be found trees which are typical of low rainfall. Climate, then, as a guide towards the distribution of trees is almost useless. Where these two factors are most favourable there are found the finest forests we possess. But the most favourable conditions of these two are not usually found together, and there result, at times, areas which are devoid of forest cover. The clear definition of the conditions of the environment here demand careful investigation so that trees may be introduced which will add materially to our wealth.

Public interest lies naturally in the use of land either for agriculture or for forestry. These two are complementary, not antagonistic. They provide for the most economical use of all the land in the State. Very little may be regarded as useless, that is, outside the realm of either of these two activities. Our waste land lies mostly in the north-west of the State where the rainfall is low. Both forestry and agriculture minister to the needs of the community, and as agriculture involves close attention to the soil, only the better soils are used for that purpose. Forestry has to be content with inferior soil conditions or with land that cannot successfully be utilized for agriculture. It has already been mentioned that the Otway and South Gippsland areas are, in so far as soil is concerned, really agricultural, but owing to the quantity and quality of the timber produced they are, from an economic point of view, better considered as forest lands. Areas with a rainfall below 30 inches may be said generally to be claimed by agriculture, but it is in this region that the very valuable forests of *E. sideroxylon* occur. Between 30 and 40 inches of rainfall, the soil is the determining factor in the use of the land. Above 40 inches, forestry in its wide application has undoubtedly first call. Forestry ultimately must

be made to include the protection of all the catchment areas as well as the production of timber. The protection of the great gathering grounds of our irrigation systems is as vital, ultimately, to agriculture as the cultivation of the land itself. These gathering grounds are the homes of several species whose protection from fire is vitally necessary. Within the 40 inch isohyet there are two outstanding conceptions of forestry, water conservation and timber production. These two are in part interlocked, but not wholly so. The application of true forestry practice to forests of *E. gigantea* is at once doing everything for water catchment as for timber production. Practice, however, can only be applied successfully if the environment of the species concerned be thoroughly understood. All practice must have reference to the habits of the tree or trees concerned and their reaction to those habitats. Above the forests of *E. gigantea, E. coriacea* is mainly found. It is in places freely interspersed with *E. rubida,* but ultimately only *E. coriacea* remains. These forests, if indeed the ultimate scrub form of this species may be so designated, are of value only in retarding the melting of the snow. These have, strange to say, been severely damaged by fire. This may be seen on many of the alpine peaks. Above this belt of trees are bare areas so far as trees or scrub are concerned.

The area of the State having a rainfall of 40 inches or over amounts only to 14 per cent. of the total area. Only a fraction of this 14 per cent. is carrying trees of economic value. It is this area in particular where a complete knowledge of the habitat is so important to the welfare of the State. As has been remarked before, the geological factors exercise an enormous modifying influence on the climatic factors, and much of this 14 per cent. is at present waste. It is only by a full knowledge of the laws of tree distribution that this area, which is our most important for both water catchment and forestry, can be made more valuable and minister more fully to the needs of the community.

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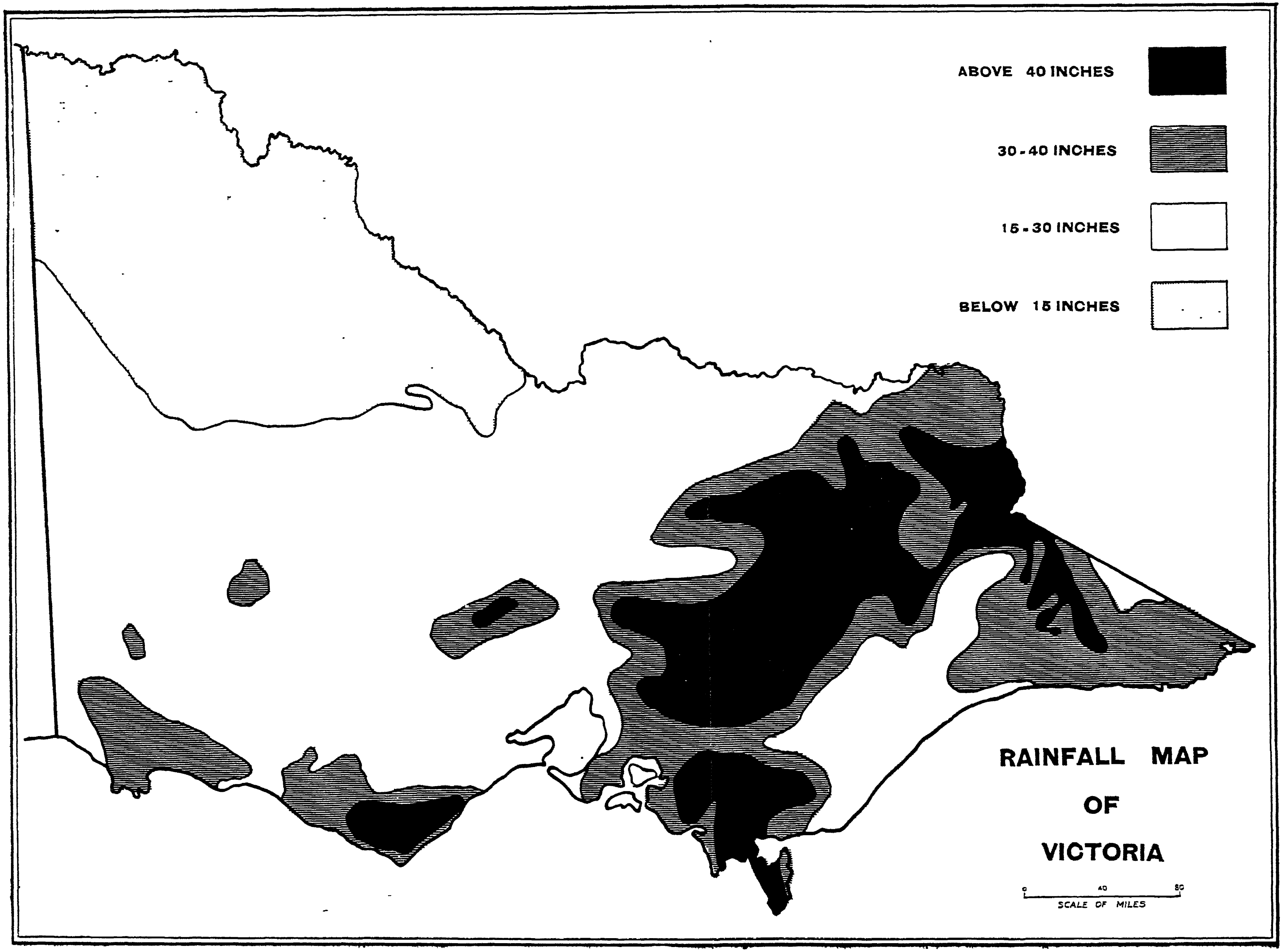
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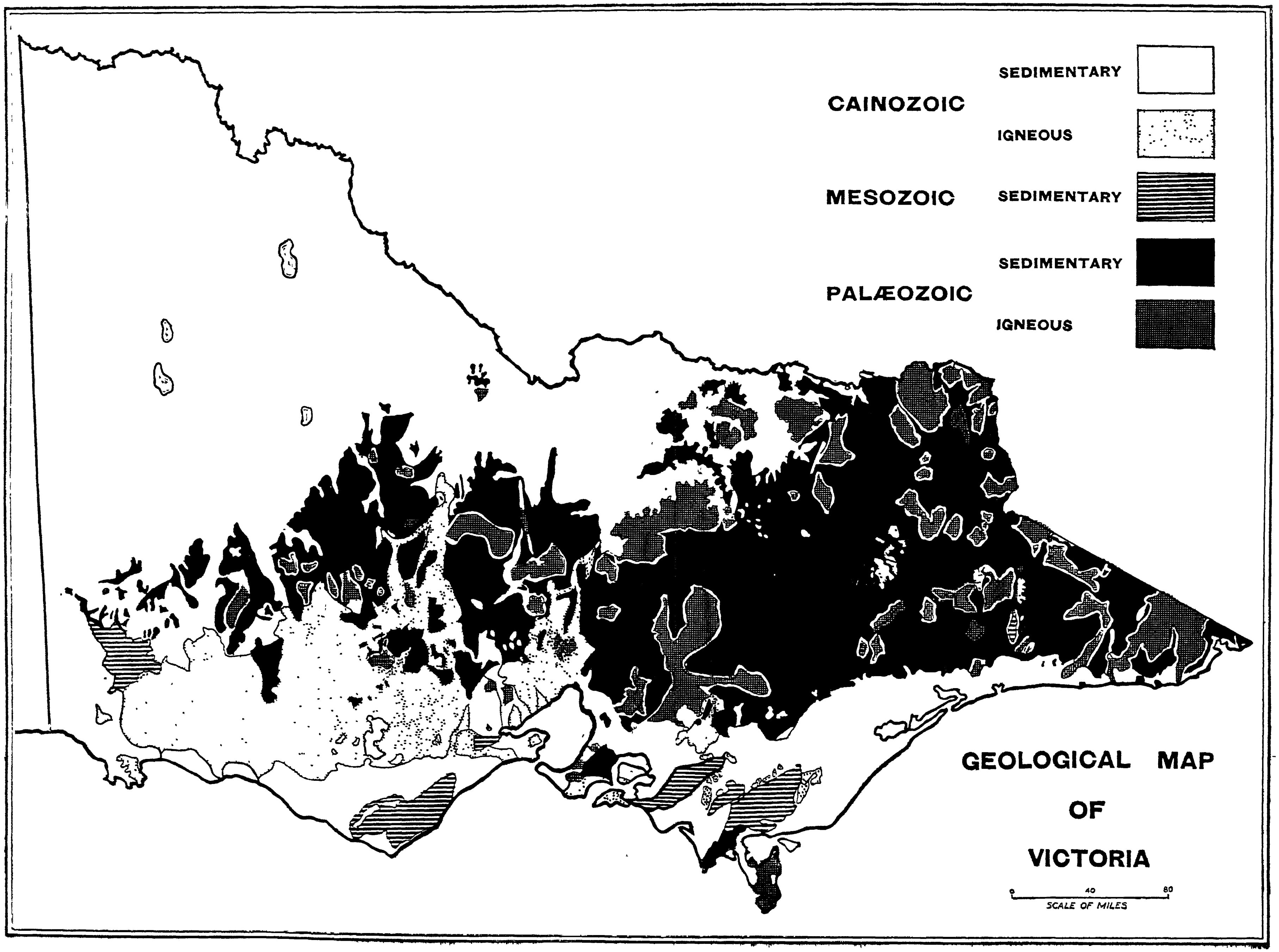
CAINOZOIC
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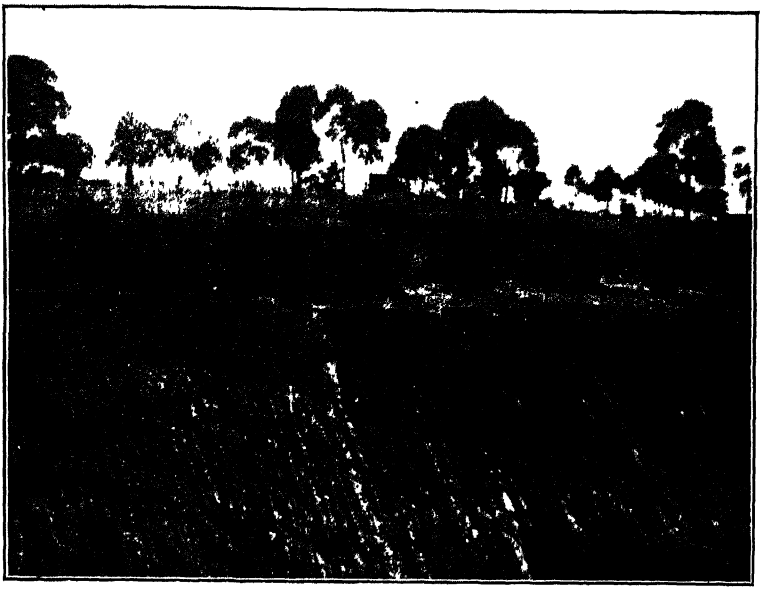

FIG A.

Silurian rocks showing the almost vertical strata and the very thin layer of soil. Mixed forest of *Eucalyptus macrorrhyncha*, *E. polyanthemos* and *E elaeophora*. Eltham

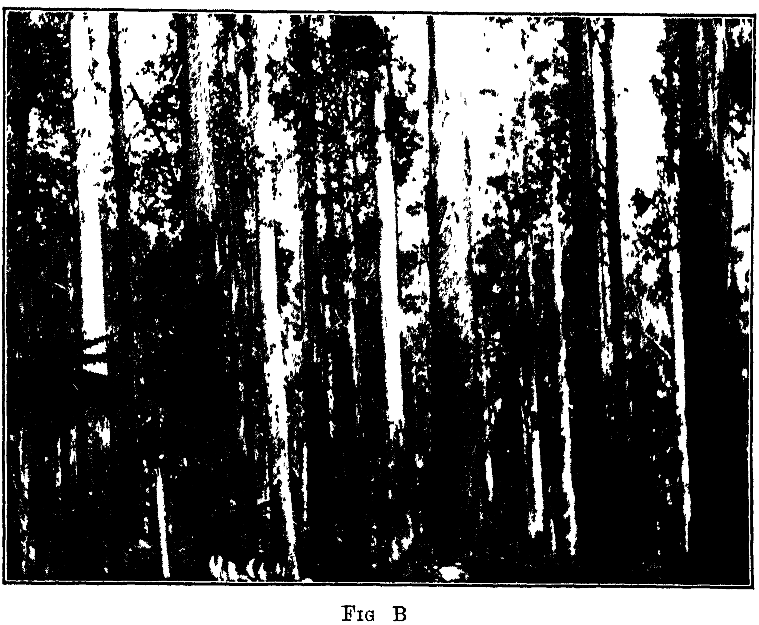

FIG B

Pure forest of *Eucalyptus regnans* growing on granodiorite. Annual rainfall 55 inches.

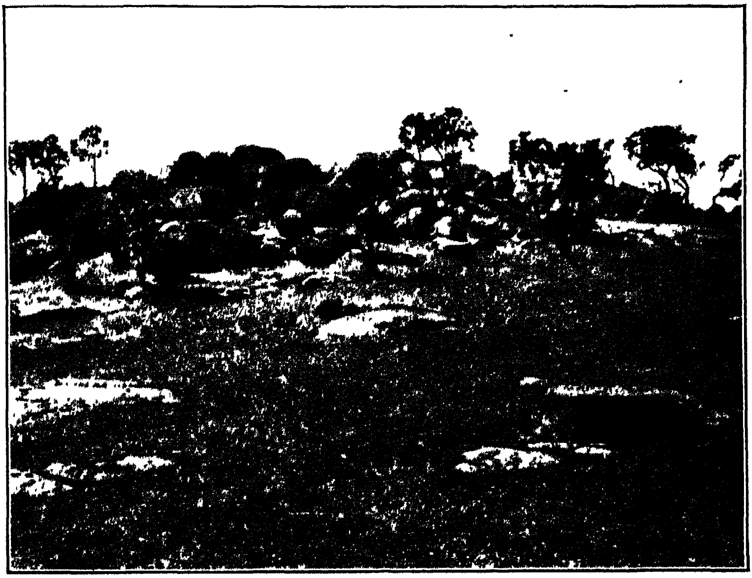

FIG. A.

The most northerly outcrop of granite in Victoria. Rainfall 15 inches. *Acacia implexa* and *Casuarina stricta.* No species of *Eucalyptus* is present. Wycheproof.

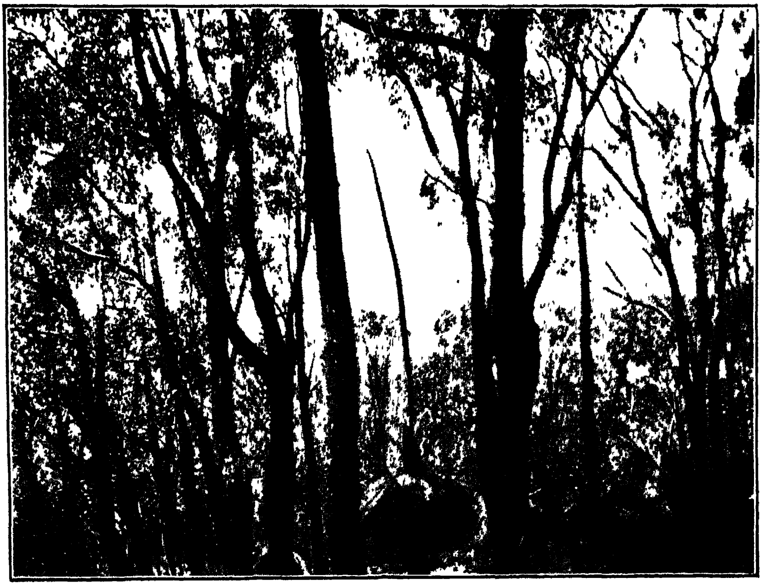

FIG. B.

Eucalyptus macrorrhyncha, *E. elaeophora* and *E. polyanthemos* on granite, associated abundantly with *Xanthorrhoea australis*. Glenrowan.

FIG. A.
Typical specimens of *Eucalyptus rostrata* on the basalt plains Somerton.

FIG B
Mallee scrub on Ordovician sediments. *Eucalyptus Behriana* and *Eucalyptus viridis* Inglewood.

Fig. A.
Pure forest of *Eucalyptus rostrata* on the banks of the Campaspe River.

Fig. B
Pure forest of *Eucalyptus coriacea* var *alpina* on Mt Hotham Elevation 5300 feet

Fig A.
Pure forest of *Eucalyptus gigantea* north of Wood's Point. Elevation 3300 feet.

Fig. B.
Pure forest of *Eucalyptus regnans* destroyed by fire 20 years before the photograph was taken. Otway Ranges.

Fig. A

Increase in the growth of bracken fern due to the opening of the crown canopy as the result of fire. Mt. Stanley.

Fig. B.

Mixed forest of *Callitris calcarata* and *Eucalyptus elaeophora*. Note the large granite boulder in the foreground. Beechworth.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II, 1930.]

ART. XX.—*Microglossa and Melitribus, New Genera of Australian Bees.*

By TARLTON RAYMENT.

(With Plate XXI)

[Read 12th December, 1929; issued separately 13th March, 1930.]

During the summer of 1929, *Eucalyptus calophylla* had a crop of flowers that almost eclipsed the foliage, and I was able to collect a large number of honey-gatherers. I have identified over one hundred species, and have many more to be worked out. This is probably the largest number recorded to visit one botanical species. I could not collect many of the bees that hovered over the tops of the trees. See Sir John Lubbock (1).

Among the debris of pollen-grains, broken leaves and flowers that accumulated in the bottom of my collecting-net, I recovered a few very small insects that had no difficulty in passing between the fine threads of the cheese-cloth. They were so minute that I did not, at first, make any special effort to retain them, and so lost numerous specimens. It was not until I examined the debris at my leisure that I appreciated the significance of their structure.

The species of the new genus *Microglossa* are the smallest bees yet described. I submitted the types to Mr. Henry Hacker, of the Queensland Museum, who states that *Microglossa* is smaller than the bees of the genus *Turnerella* (2). The integument is black, highly polished, and the markings are light yellow. The head is large and square, and the development of the genae is abnormal. The mandible is notched after the manner of *Prosopis*. The clypeus is remarkably small, and consequently the frons is exceedingly long. The yellow face-markings, too, are suggestive of *Prosopis* (3).

The antennae are inserted very low down, and that feature is often seen in *Euryglossa*. The scape is dilated at the apex, and hollowed out in such a way that it is capable of partially receiving the first segment of the flagellum when it is bent down. Along the edge of the cavity is a fringe of stiff bristles, and I can find nothing like this on any other Australian, American or European bee that I have studied. The third segment of the flagellum is the shortest, and the others are wider than long, and so conform to the type of *Euryglossina* (4). The outstanding feature is the paucity of pore and peg structures compared with the numerous and varied organs of the honey-bee's antennae.

The head capsule, from the rear, reveals the enormous cheeks and the wide, low fossa or cavity which receives the submentum of the short proboscis. Text-fig. 1, No. 6, illustrates the rudimentary character of this organ. The palpi are of four segments, and the basal one is short and stout, approaching the square form found in *Euryglossa*. The whole head, especially the thickened development of the vertex, is very suggestive of that genus.

Order HYMENOPTERA.

Suborder HETEROPHAGA.

Division COLLETIFORMES.

Family PROSOPIDIDAE.

Microglossa, new genus.

Minute black and yellow almost hairless bees. Length, 2-3 mm. Head very broad, laterally a wide, short oval, the occiput and the post-genae of remarkable development, the submentum barely visible in the low, wide fossa of the proboscis; face-marks, when present, yellow; frons, owing to the antennae being inserted so low down, is excessively large and is minutely sculptured; clypeus hardly visible, usually yellow and extremely narrow; supraclypeal area is pyramidal in form, and is much more prominent than the clypeus; vertex broad and rounded, the small ocelli being placed in an equilateral triangle; compound eyes converge slightly above, the facets are large; genae full and rounded; labrum small, hidden from view; mandibulae yellow or amber, those of the female having two strong teeth; antennae submoniliform, the scape being slightly dilated, and there is a depression, at the apical end, of size and shape to receive the first segment of the flagellum.

Prothorax shows as a very narrow collar with minute rugae; tubercles, either yellow or black; metathorax convex, with puncturing of a scattered nature, and extremely minute sculpture; scutellum does not present any generic characters. Abdomen is long and narrow, greatly contracted basally and apically; there are a few hairs apically.

Legs slender, almost destitute of hair; the antenna-cleaner of the anterior leg has a long serrated malus of Halictine form, and the velum is oval, of Prosopoid form; tarsi diminishing in size, the first being the longest; claws simple and the empodium large; hind calcariae with a large number of fine long serrations, of pale colour. Wings clear, the anterior ones widely rounded at the apex; nervures are heavy, the radius reaching the costa at an obtuse angle, the first recurrent entering the first cubital cell before the first intercubitus. Cells: the radial is abnormally large, the first cubital and the only discoidal being

equal; the second cubital is smaller; pterostigma of great size, being almost a half circle, and dark in colour; hamuli extremely weak, five in number.

Males slightly smaller, with yellow faces and longer antennae.

Genotype *M. longifrons*, n. sp.

Allied to *Euryglossidia* of Cockerell by the neuration of the wings, but these almost hairless bees are undoubtedly the smallest yet described, and are easily separated from *Euryglossidia*, which has a narrow pterostigma, and is much larger (5).

MICROGLOSSA LONGIFRONS, new species.

Male: Length, 2·5 mm. approx.

Head broad, black, bright, laterally a wide oval; face-marks pale yellow, wider than clypeus, oval at apex, reaching two-thirds up orbital margins; frons excessively large, black, bright, with a coarse tessellate pattern, a few punctures; clypeus excessively narrow, yellow, almost hidden from view; supraclypeal area large, yellow, apex of pyramidal form; vertex black, broadly developed, with three black small ocelli in an equilateral triangle; compound eyes black, converging above, facets large; genae black, a large yellow patch at base of mandible, minute, stiff white hair; labrum yellow, very small; mandibulae acute, yellow, a minute red spot apically; antennae with scape slightly dilated, yellow, flagellum dark amber, prominent white hair.

Prothorax hardly visible from above, black, rugose when viewed laterally. Tubercles yellow, with white hair. Metathorax black, shining, with a coarse tessellate pattern, a few scattered punctures, half-a-dozen very minute white plumose hairs just over the tubercles; scutellum similar to mesothorax; metathorax excessively large, forming half the thorax, black, posteriorly a transverse rim, a large dome-shaped area rugose, superimposed is an isosceles triangle, with transverse rugae. Abdomen with dorsal segments black, shining basally, obscurely lighter, first very large, forming half the abdomen, a few minute white hairs at apex; ventral segments similar.

Legs, anterior and median yellow, hind femora dark amber; tarsi light amber; claws light amber; hind calcariae short, broad, pale, almost white, shaped like an isosceles triangle. Tegulae pallid, dull. Wings hyaline, slightly iridescent; nervures dilute sepia, heavy, basal not arched, falling a long way short of the nervulus; cells, first cubital and the sole discoidal of equal size, second cubital smaller; pterostigma dilute amber, with a darker margin, half a circle in form, very large. Hamuli exceedingly weak, five in number.

Locality.—Sandringham, Victoria (February 20th, 1929).

Collected from a flower of *Eucalyptus calophylla*. (Rayment).

Type in the collection of the author.

Allies: *M. rufitarsus*, n. sp., which has a fine striation covering the frons, and *M. bimaculata*, n. sp., which has black tubercles.

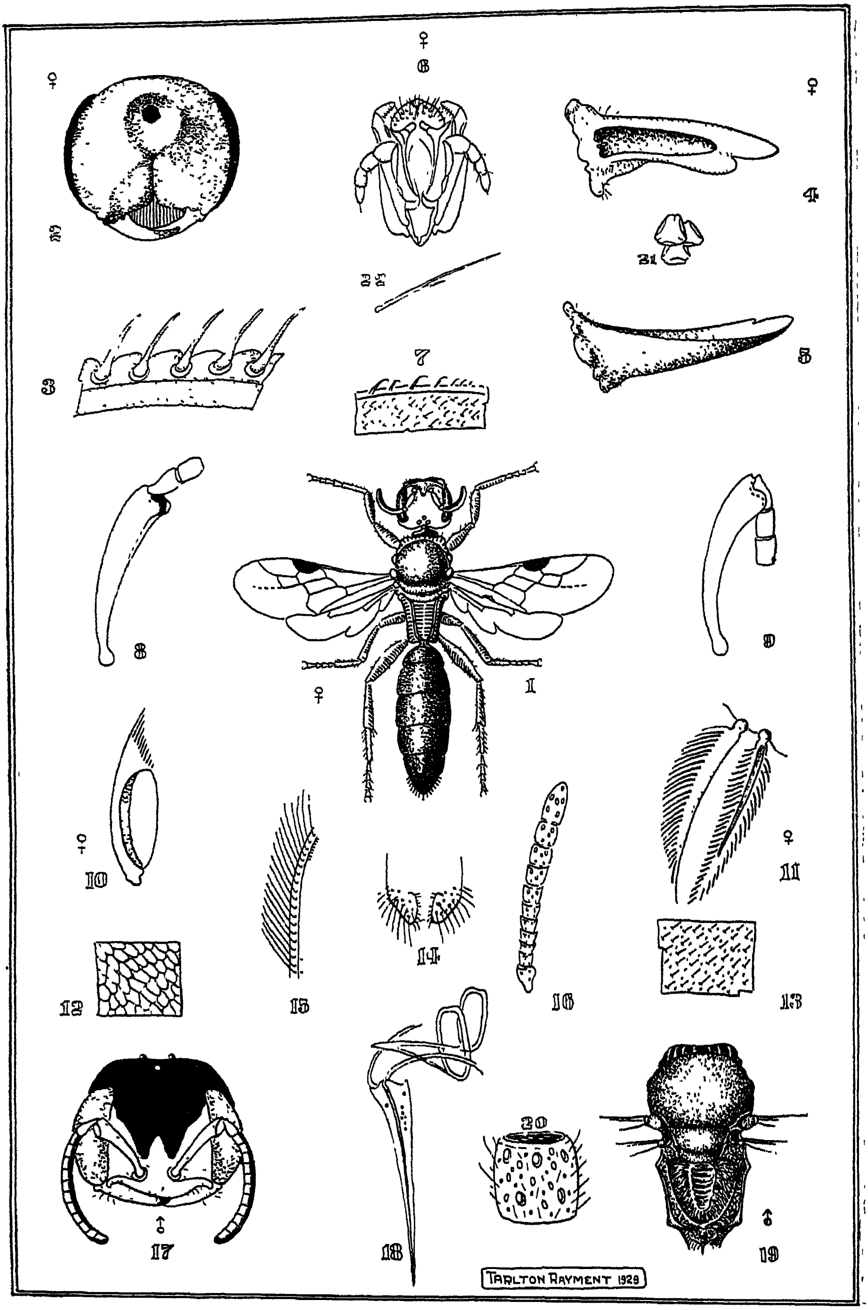

Fig. 1—*Microglossa longifrons,* gen. et. sp.nov.

MICROGLOSSA RUFITARSUS, new species.

Female: Length, 2·5 mm. approx.

Head very wide, black, shining, laterally a wide oval; face-marks nil; frons with an extremely delicate striation covering the large area, and scattered punctures visible under a one-inch lens; clypeus extremely small, yellowish amber; supraclypeal area comparatively large; of pyramidal form, obscure amber; vertex broad, with wine-colour ocelli; compound eyes black, converging above, large facets; genae black, shining, with striation and punctures similar to the frons; labrum pale amber; mandibulae yellow, with reddish tips, two strong teeth; antennae submoniliform, pale amber beneath, darker above, the scape dilated, with a depression which receives the first segment of the flagellum.

Prothorax just visible from above as a narrow area finely rugose. Tubercles black, shining. Mesothorax black, shining, with the delicate striate pattern and puncturing of the frons; scutellum with the colour and sculpture of the mesothorax; post-scutellum black, rough, narrow; metathorax black, excessively large, forming half the thorax, a large, wide, lunate area rugose, fine rugae covering the angle of truncation. Abdomen with dorsal segments showing a delicate, transverse striation, black, shining, with a few punctures; ventral segments similar.

Legs amber, except femora and hind tibiae, which are suffused with black; tarsi amber; claws amber; hind calcariae amber, with numerous minute serrations; tegulae black, shining, with a ferruginous margin. Wings hyaline, iridescent, widely rounded at apex; nervures dilute sepia, heavy, the basal not arched, radius nervure meeting the costa at an obtuse angle;

FIG. 1.—*Microglossa longifrons*, new species.

1 Adult female: note the scarcity of hair and the large pterostigma. 2. Posterior view of head-capsule, showing the abnormal genae, and the very small fosse which receives the glossa. 3. A row of stiff bristles fringe the hollow at the apex of the scape. 4. Anterior view of mandible, showing the strong teeth. 5. Lateral view of mandible, exhibiting its spoon-like hollow. 6. The short wide tongue with maxillae; the labial palpi have a thick basal joint. 7. The hamuli, or hooklets, of the small wing are irregular and few in number. 8. The scape, with the flagellum extended, to shew the cavity. 9. Scape with the first joint of the flagellum resting in the hollow at apex. 10. Antenna-cleaner, on the tibia of the front leg, has numerous serrations. 11. Two views of the hind calcariae, or tibial spurs; the left-hand one is viewed laterally. 12. Portion of the minute sculpture of the integument highly magnified. 13. Minute hairs, and still more minute "pegs," cover the surface of the wings. 14. The extreme tip of the abdomen has a rima or furrow. 15. The edges of the wings have a fringe of comparatively long hair. 16. Flagellum, with joints wider than long, has three kinds of pore organs. 17. Anterior view of head-capsule of male. Anterior view of the "face", the clypeus and supraclypeal area, together with the lateral face-marks, are pale primrose-yellow. 18. The sting of the female is very wide at the base, and there are several pores that may be olfactory in function 19. The thorax of male, showing the ridged prothorax, the convex mesothorax, and the sculpture of the large metathorax. 20. One of the antennal joints highly magnified to show three kinds of pores. 21. Pollen-granules (*Eucalyptus*) removed from the hairs at the apex of abdomen. 22. A forked hair from near the base of the mandible or jaw. The bee had to be dissected, and the parts mounted for study with a 1-6th in. objective, before a forked hair could be identified.

cells: first cubital and the sole discoidal of equal size, second cubital smaller, radial abnormally large; pterostigma large, dilute sepia; hamuli of weak development, five in number.

Locality: Sandringham, Port Phillip (February 20th, 1929), and Malvern, Victoria.

Collected on flowers of *Eucalyptus calophylla.* (Rayment).

Type in the collection of the author.

Allies: *M. longifrons,* n. sp., which has yellow spots on the genae.

MICROGLOSSA BIMACULATA, new species.

Female: Length, 3 mm. approx.

Head black, wide, shining; face-marks, two minute yellow spots near mandibulae; frons excessively large, shining, minutely striate, with scattered punctures; clypeus excessively narrow, yellow; supraclypeal area resembling a yellow pyramid, darker apically; vertex with wine-pink ocelli; compound eyes blackish, slightly converging above; genae black, shining, with a large yellow spot at bases of mandibulae; labrum yellow; mandibulae yellow, with reddish tips, two strong teeth; antennae with scape black, and a depression to receive the first segment of flagellum, which is dark above and amber beneath; inserted just above mandibulae.

Prothorax black, rugose; tubercles black, shining; mesothorax black, shining, finely tessellate, with scattered punctures; scutellum similar to mesothorax; metathorax long, transversely striate, black. Abdomen with dorsal segments black, shining, margins narrowly lighter; ventral segments similar.

Legs amber, anterior femora, middle and hind coxae, femora and tibiae all suffused with black; tarsi amber; claws light amber, with large dark empodium; hind calcariae pale, with numerous fine teeth; tegulae shining, black. Wings hyaline, iridescent; nervures dark amber, basal straight, falling far short of nervulus; cells, first cubital and the sole discoidal equal, the second cubital smaller; pterostigma dark amber, large; hamuli weakly developed, five in number.

Locality: Sandringham, Port Phillip, Victoria (February 20th, 1929). Collected from flowers of *Eucalyptus calophylla.* (Rayment).

Type in the collection of the author.

Allies: *M. rufitarsus,* n. sp., which has no spots on cheeks and no face-marks.

Melitribus, a New Colletid Bee.

The number of honey-gatherers described from West Australia is not large, but I am convinced the State has perhaps more species than the eastern portion of the Commonwealth.

Only a few collectors have given the bees much attention, chiefly because Australia owns so few of the types described by Fred. Smith (6) in England, and, later, by Professor Cockerell (7) in America.

Henry Hacker (8) lists only one species of *Exoneura* for West Australia, yet Mr. T. Greaves, who has just returned from a collecting excursion, brought back great numbers of these reed-dwelling bees, which, he states, were the most numerous, and Mr. J. Clark, sometime of Perth, but now of Melbourne Museum, assures me that this is correct. I propose to publish a list of these bees at a later date.

Among the large honey-gatherers he collected was a fine black male that could not easily be allied, except to *Gastropsis victoriae*, which was described by Professor Cockerell (9), and, though he thought it should have formed the type of a new genus, he deferred doing so. He recognised many characters of the European *Melitturga* and discussed that aspect in 1904 (10), but the tongues are altogether different. This new bee provides additional material for study, and I consider it advisable to erect the new genus *Melitribus*, and append the generic diagnosis and specific description. The families are those of Cockerell and Robbins (11) and the neuration of the wings is based on the arbitrary method of Rohwer and Gahan (12).

Family COLLETIDAE.

Melitribus, new genus.

Large, black, hairy bees. Length, 15-17 mm.

Head with occipital region but little developed, the glossa being short, wide and bristly; the paraglossae short and thick; six segments in the maxillary palpus, and four in the labial palpus; face-marks are confined to coloured hair; frons constricted by the enormous development of the compound eyes; clypeus convex, the anterior edge with two noduliform processes; supraclypeal area small; vertex weakly developed, the large ocelli placed nearer the insertion of the antennae; compound eyes greatly developed, converging above, prismatic emerald-green in life; genae obscure; labrum hidden; mandibulae strong, bidentate; antennae with large scape, third antennal joint very long and slender.

Prothorax not visible from above; tubercles of no significance. Mesothorax large, convex, and hairy; scutellum large, higher than the disc of the mesothorax; postscutellum of little significance; metathorax granular, angles prominent, but hidden under much hair; abdominal dorsal segments shining, hairy, but bands not conspicuous; ventral segments with much long hair.

Legs stout, coxae triangular, large; tarsi with first segment narrow; claws deeply bidentate; hind calcariae finely serrated

in male; malus or strigil somewhat truncate. Tegulae with large tuft of plumose hair; wings dusky or subhyaline; nervures heavy, the recurrents entering the middle of the cubital cells; cells: radial long and narrow, the second and third cubitals contracted at apex; pterostigma obsolete; hamuli seventeen in number, well developed.

Genotype *M. greavesi*, n. sp.

Allies: Professor Cockerell suggests some alliance with the European genus *Meliturga*, but that has a long, fine glossa. *Gastropsis victoriae*, then, becomes *M. victoriae* (Ckll.). I have a specimen of *Meliturga clavicornis* Latr. from the Paris Museum, and the second segment of the flagellum is reduced, though it is short. Professor Cockerell described the "first joint" as being attenuated, though I think he meant "second." The compound eyes of *Meliturga* are hairy, like those of *Trichocolletes* and *Apis*.

MELITRIBUS GREAVESI, new species.

(Plate XX., Figs. 1-14.)

Female: Length, 16 mm. approx.

Head black, almost a circle viewed from the front; face-marks nil; the face narrowed by the great development of the compound eyes, the ocelli on an elevation almost level with the insertion of the antennae: frons shining, with a rough puncture-like sculpture under numerous long, black, plumose hairs, a median patch of dull white hair; clypeus large, prominent, black, shining, coarsely punctured, a dense covering of long, orange-coloured plumose hairs; supraclypeal area similar to clypeus in colour and hair, but rising to a strong carina that reaches to and encloses the median ocellus; vertex with numerous black plumose hairs; compound eyes dull green, in life bright emerald, large, converging strongly at vertex; genae black, shining, numerous punctures, a dense covering of long, silvery plumose hair; labrum small, black, shining; mandibulae black, shining, with obscure red tips, and one large and one small tooth, numerous long hairs; antennae black, shining, the scapes stout, with long hair, the third segment slender and long, the flagella obscurely reddish beneath.

Prothorax not visible from above, but the mesothorax has a fringe of white hair on anterior margin; tubercles hidden under long, silvery, plumose hair; mesothorax shining black, with an obscure iridescence, densely and coarsely punctured, a thick covering of short black plumose hair on the disc, mesopleura and sternum with long pale hair; scutellum similar to mesothorax, but anteriorly with an extremely thin margin of pale white hair, posteriorly a thick fringe; postscutellum covered with long, white hair; metathorax completely hidden under long, silvery-white plumose hair. Abdomen with dorsal segments

black, shining, numerous punctures and short black hairs, hind margins obscurely and narrowly lighter, a minute fringe of short white hair, one and two are covered with numerous white hairs; ventral segments black, shining, with much long white hair.

Legs black, coxae and long trochanters with white hair, femora with a few white and many black hairs, tibiae with dense, coarse, black, forked hairs; tarsi reddish, with long golden hair; claws bifid, long, reddish amber; hind calcariae with long fine serrations, amber; malus of strigil truncated. Tegulae shining black, with a dense tuft of long black hair separated from that of the mesothorax by a fine crescent of white hair. Wings subhyaline, anterior 12 mm. Nervures strong, blackish-brown, first and second recurrents entering second and third cubital cells at about the middle, basal falling short of the nervulus; cells: second and third cubitals sub-equal, contracted at apex; pterostigma obsolete; hamuli seventeen in number, strongly developed.

Locality: Bungulla, Western Australia (November 1st, 1929). Collected by Mr. Tom Greaves, the Secretary of the Melbourne Entomological Club, on flowers of *Callistemon.*

Type in the collection of the author.

Allies: Near to *Gastropsis victoriae* Ckll., this large and beautiful bee is most distinctive. The white hair of the metathorax and the first and second abdominal segments is combined as a wide median band across the black, shining body, and is suggestive of *Megachile lucidiventris.*

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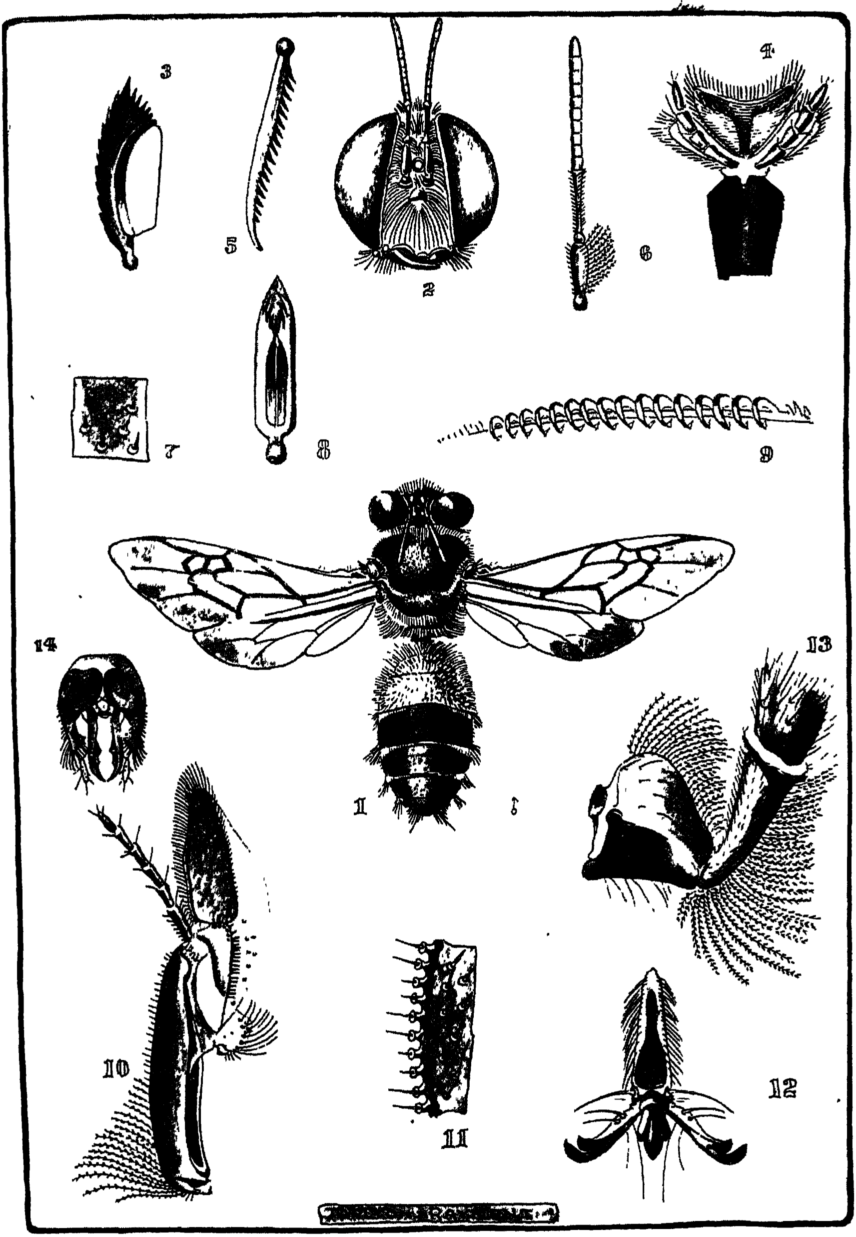
Explanation of Plate XXI

Melitribus greavesi, new species.

Fig. 1.—Adult male.
Fig. 2.—Front view of head.
Fig. 3.—Truncated strigil or antenna-cleaner.
Fig. 4.—Glossa or tongue and palpi.
Fig. 5.—Serrated calcar.
Fig. 6.—Antenna showing slender joint.
Fig. 7.—Short, peg-like hairs of the wing.
Fig. 8.—Another view of strigil showing cavity at top.
Fig. 9.—The seventeen hamuli are well developed.
Fig. 10.—Maxilla and palpus, showing the long plumose hairs.
Fig. 11.—Edge of maxilla more highly magnified.
Fig. 12.—Underneath of fifth tarsal joint with claws and empodium.
Fig 13.—The coxa is large and angular.
Fig. 14.—Genitalia.



Melitribus greavesi. A new Colletid Bee.

[PROC. ROY. SOC. VICTORIA, 42 (N.S.), PT. II., 1930.]

ART. XXI.—*Origin of Mud Island, near Paynesville, Victoria.*

By W. G. WOOLNOUGH, D.Sc.

(Communicated by W. Baragwanath.)

(With Plate XXII.)

(Published by permission of the Honourable the Minister for Home Affairs for the Commonwealth.)

[Read 12th December, 1929; issued separately 13th March, 1930.]

Introduction.

During 1928, a small "island" suddenly appeared in Lake Victoria, Gippsland, close to the shore of Pelican Point, on Sperm Whale Head, and about 8 miles west of Paynesville. The suddenness of the apparition, the fact that emission of inflammable gases accompanied and followed the rise of the island, and that, about simultaneously, decisive traces of crude oil were obtained in Government bores at Lakes Entrance, combined to give colour to the hypothesis that the mud island itself was produced by an "eruption" from the underlying oil beds (1, p. 29). A critical examination of the facts, however, appears to the author to lead to a totally different explanation.

The island rose with remarkable suddenness, and, at its maximum development, attained a length of some 85 feet with a width of 30 feet and a height of 4 feet above the level of the lake.

When it was visited by the author, at the beginning of May, 1929, the subaerial portion of the "island" had almost entirely disappeared: only a few small mud lumps still rose above the surface of the water. The mud was so soft that the observer sank to the knees in it. From numerous small vents, strings of gas bubbles rose intermittently through the water. Spasmodic periods of activity, at irregular intervals, continue to the present day.

Geology and Physiography of the Area.

The Gippsland Lakes extend from Sale on the west to Lakes Entrance on the east, a distance of some 55 miles. They are separated from the sea by a narrow sand hummock, through which a restricted outlet is maintained, by means of training walls, with some difficulty. They represent, then, a very con-

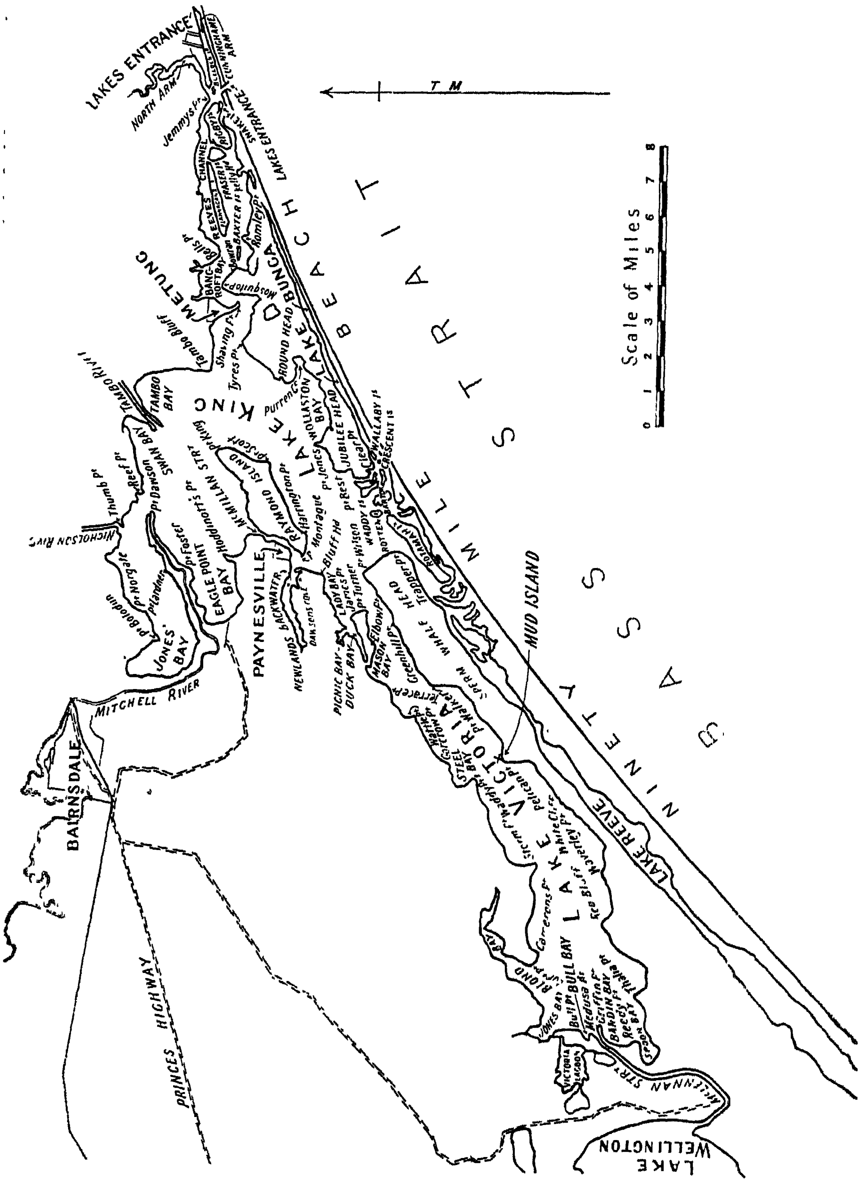

LAKES ENTRANCE
NORTH ARM
LAKE KING
BUNGA
METUNG
LAKE VICTORIA
LAKE WELLINGTON
LAKE REEVE
MUD ISLAND
NINETY MILE BEACH
BASS STRAIT
T M
Scale of Miles
0 1 2 3 4 5 6 7 8
BAIRNSDALE
PAYNESVILLE
MITCHELL RIVER
NICHOLSON RIV
TAMBO RIVER
TAMBO BAY
SWAN BAY
JONES' BAY
EAGLE POINT BAY
RAYMOND ISLAND
WOLLASTON BAY
JUBILEE HEAD
ROUND HEAD
NEWLANDS BACKWATER
PICNIC BAY
DUCK BAY
MASON BAY
STEEL BAY
BULL BAY
BARDIN BAY
SPOON BAY
VICTORIA LAGOON
PRINCES HIGHWAY

FIG. 1.

siderable area of salt lake, in which tidal action is inappreciable.

The whole structure is of the nature of a drowned river valley of fairly mature development, and is comparable with Port Phillip, Western Port, and other drowned valleys on the Australian coast.

In one respect, however, the Gippsland Lakes are unique; Into them drain several of the largest of the coastal rivers of Victoria. These include the Tambo, Mitchell, Thomson and Latrobe; all streams of some magnitude, draining a large, fertile and relatively well populated district.

Consequently, much aggradation has taken place in the lakes, and they are littered with islands, large and small, and contain innumerable shoals.

As a consequence of their structure, and particularly because of their tidelessness, some of the rivers have developed deltas of a type almost unique. These are particularly well marked in the case of the Tambo and Mitchell rivers, which fall into a broad and well protected part of the Lakes. These streams have built out long "natural jetties" of silt, and have pushed their mouths forward into the lake by the construction of natural canals with these jetties as training walls. (Plate XXI., Fig. 1.)

On a small scale they are strikingly similar to the structures formed at the mouths of the Mississippi, itself considered abnormal, amongst the rivers of the world, as regards the structure of its delta. (See below, description by Shaw.)

In the immediate vicinity of the Lakes, the geological formations are almost exclusively Cainozoic in age.

There are very extensive areas of Recent (and probably Pleistocene) deposits directly associated with the activities of the present day rivers and of their immediate ancestors.

Tertiary formations are extensively developed, and are represented by an upper series, the Kalimnan, and a lower series, the Janjukian, which are Pliocene and Miocene, respectively. These have been shown to attain thicknesses of 250 feet of Kalimnan and upwards of 1200 feet of Janjukian in the bores already sunk. The Janjukian beds consist chiefly of polyzoal marls. At the base these give place to a glauconitic facies, which rests directly on a weathered surface of granite and Palaeozoic rocks.

The Tertiary beds are almost horizontal, and, in the vicinity of Lakes Entrance, dip in a west-south-westerly direction at a very uniform rate of some 50 feet to the mile. Very exhaustive search and detailed mapping by officers of the State Geological Survey have failed to reveal any appreciable disturbance of this very uniform structure, so far as the eastern portion of the Lakes is concerned.

It is possible that future investigation may reveal some disturbances at the western end, near Sale, but no satisfactory evidence is known of any folds and faults in the middle section of the Lakes Area.

At four points within a radius of 3 miles of Lakes Entrance calyx bores have been sunk by the Mines Department. In three of these decisive evidence of the petroliferous nature of the basal beds of the Tertiary System has been obtained, in the form of a rather heavy oil saturating the green sandstone cores. Unfortunately, artesian water was struck coincidently with the oil; and no separation has been effected as yet.

At one point, near the head of a small stream known as the Mississippi (no relation to the Father of Rivers referred to somewhat extensively below), there is a small inlier of granite, which supplies the material for the construction and maintenance of the training walls at Lakes Entrance. It seems highly probable that this is an isolated peak on a "buried ridge" of granite of which the main body outcrops some miles to the north near Colquhoun Railway Station.

The hinterland of the Gippsland Lakes comprises some of the roughest and most picturesque mountain scenery in Australia, forming, as it does, the southern edge of the Australian Alps. These mountains consist, for the most part, of highly contorted and considerably metamorphosed Older Palaeozoic rocks of various types and ages, intruded by immense bosses of granite. Large areas about the headwaters of the Mitchell and Thomson Rivers are occupied by less disturbed and less altered epicontinental formations of Upper Palaeozoic age. The structure of this hinterland, however, does not enter into the present discussion.

Description of the locality near "Mud Island."

Sperm Whale Head is low for the most part, though scrub-covered sand dunes, ranging to heights of over 30 feet above water level, occur at its western end.

On Sperm Whale Head there are depressions, only a few inches above water level, which are occupied by shallow lagoons, dry in certain seasons, and filled with fine grained marl, which has been worked to some slight extent as a fertiliser. These are very similar to lagoons on the Coorong in South Australia, and to the north of Bunbury in Western Australia. The workings are very crude, and no output is obtained at present. To facilitate the shipping of the product, a small jetty was built on the landward side of the headland in 1927. Since that time the accumulation of sand banks along the shore has been so extensive that the end of the jetty is now high and dry. This is a fact of great scientific importance, indicating, as it does, a very recent change in the physiography of the district, which has led to excessive sedimentation along the shores of Sperm Whale Head. This will be referred to later.

A similar sand spit has formed about 20 chains to the north-east of the jetty, and Mud Island has developed immediately offshore from the point of the sand spit and at a distance from it

of about 15 feet. At the time of our visit, this sand spit was roughly triangular in shape, with its base along the old shore of Pelican Point, and its apex pointing towards Mud Island and the lake. Its base was some 50 yards long and its width, at right angles to the shore, about 30 yards. The subaqueous slopes are extremely steep, the material standing at the maximum angle of repose: so steep, in fact, that we stepped ashore, dry footed, from the bows of the launch by which we had arrived.

The material of the sand spit is rather coarse sand, and is entirely unconsolidated. The instability of the structure was well illustrated by the fact that, immediately on landing, it was noticed that there were freshly developed cracks running right across the spit from side to side. These illustrated, with diagrammatic clearness, the phenomena of normal faulting on a "pocket edition" scale. The outer point of the spit had subsided about an inch,

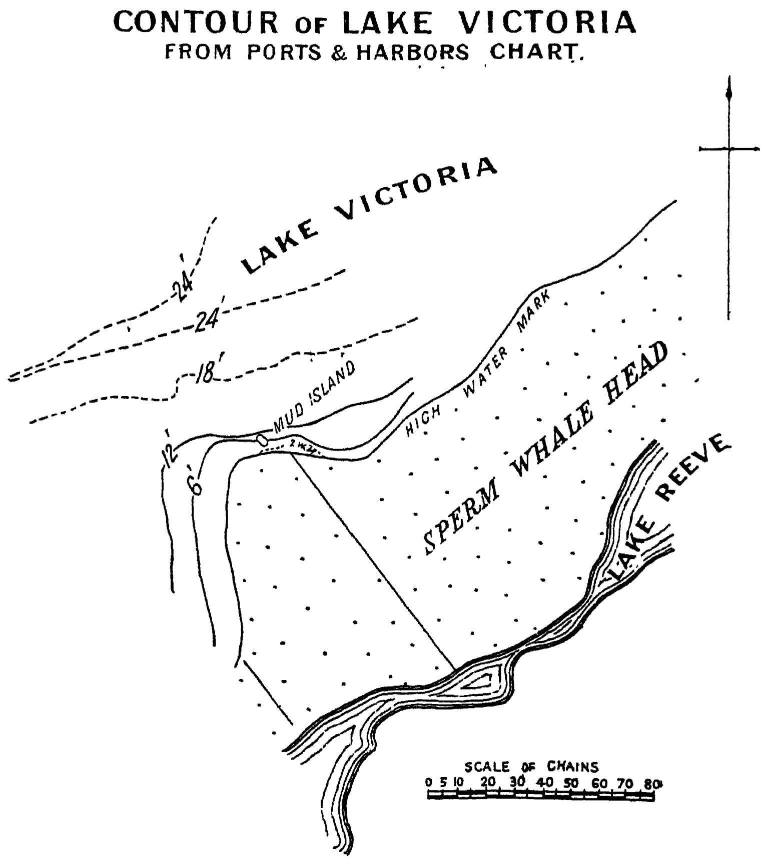


FIG. 2.

and the "fault crack" was still sharp and unweathered. Even as we watched, tiny landslips were taking place, and the very moderate breeze which was blowing was moving quite an appreciable amount of sand from the sharp edge of the crack. The conclusion is irresistible that the fault had just taken place, and that the impact caused by the grounding of the launch was probably sufficient to disturb the very delicate state of equilibrium of the sand spit.

The Formation of "Mud Island."

These observations lead to the conclusion that the development of Mud Island is due to no deep-seated cause, connected with the presence of oil at a depth of over 1600 feet, but that the mud bank was produced by the overloading of the incompetent mud foundation of the floor of the lake, through the accumulation on it of the sand spit above described.

Why should such a sand spit have formed recently, and not before?

The author considers that the explanation is to be found in the history of the district since settlement has taken place. This occurred about a hundred years ago. In its early stages it was "light pastoral" occupation. A considerable amount of ringbarking of timber took place, but it is only comparatively recently that there has been really extensive clearing in the watersheds of the Tambo, Mitchell, Thomson, and Latrobe Rivers, which discharge into the lakes. This is particularly the case with the poorer and more sandy soils of the district, many of which, as, for instance, those near Fernbank, are only now being cleared and cultivated.

Persistent overstocking, the extension of agriculture, the damage done by bush fires, road and railway construction and other types of human interference have been responsible for a recent and rapid change in the physiographic conditions of the district, and this change is eminently favourable to a marked augmentation of the rapidity of sedimentation; and, still more, to the transportation of much coarser grained sediment than formerly.

The author has noticed evidence of the same kind at many places round the coast of Australia, where sand dunes, which had long been anchored by the growth of large trees, have *quite recently* been overwhelmed by sand drift from the beaches. It seems probable that, here again, the change of conditions is attributable to man's interference with nature's equilibrium, resulting from the inception and continuance of dredging, breakwater building, harbour works, and probably, more than all, from mining and agricultural operations in the watersheds of the coastal rivers.

The date of formation of the sand spit is certainly open to argument. Local observers will undoubtedly claim that "there has been no difference since my grandfather's time." Such subjective personal impressions, unsupported by accurate objective measurements, are entitled to some weight, but not much. The growth of a sand spit, even though extremely rapid in a geological sense, is so imperceptible as to escape remark, even by trained observers.

There is some evidence, on the ground, supporting the impression that the increase in dimensions of the particular sand spit under consideration has occurred very recently. Of the growth of the sand bank near the jetty there is no shadow of doubt. At "Mud Island," the shore of Sperm Whale Head is marked, in most places, by a low bank of fine clayey sand about a foot above water mark. This, apparently older deposit, is covered with grass, and contains, near the shore line, larger and smaller ponds and lagoons. A little further back there is a low growth of ti-tree and other marsh-loving trees. These features can be readily traced just behind the sand spit, which has the appearance of having been added to the normal shore line, and of being out of harmony with the general characteristics of the latter.

A feature of Mud Island, which has been claimed as conclusive by supporters of the oil eruption theory, is the fact that the mudbank is composed largely of clay. It is stated that such clay does not occur in any quantity on the floor of the lake in the immediate vicinity. This statement has been neither verified nor disproved, so far as the author is aware, by any authentic observations.

In any case, the occurrence of such excessive amounts of clay, far from being damaging to the hypothesis put forward here, is actually one of its strongest supports, as will appear in the sequel, when similar structures in other parts of the world are described for comparison.

The proximate stages in the process of formation of "Mud Island" appear to be as follows:—

(1) After the drowning of the original mature valley of the Tambo-Mitchell-Thomson-Latrobe group of rivers, crustal equilibrium was sufficiently long maintained to permit of the silting up of the drowned valley, with the formation of a protecting bar along the seaward side, forming the Gippsland Lakes.

(2) Minor oscillations of level occurred, but need not be considered in this connection. The streams emptying into this tideless lake built out long deltas recalling, on a small scale, the mighty tentacles thrown out by the Mississippi into the Gulf of Mexico: a comparison of considerable moment. Shaw (see below) comments on the fact that the Mississippi Delta is abnormal in this respect, as compared with the other great deltas of the world.

In addition to these "natural jetties," large numbers of islands were built up in the lakes, and deposits of silt and clay, highly charged with vegetable detritus, were laid down under water. Such was the condition of affairs when the country was settled less than a century ago.

(3) Deforestation, by axe and fire, stocking, agriculture, and a little mining upset the equilibrium which had been established between the processes of erosion and deposition. More material and coarser material was swept down by the streams, altering the nature of the upper levels of the lake deposits, and piling up relatively extensive, coarse-textured and unconsolidated sand banks and spits locally.

(4) Reaching the limits of supporting capacity in places, the foundations of these sand spits give way, not by bodily collapse, but by lateral squeezing out of the more plastic clayey layers between and, in some cases, through the overlying less plastic strata. The laterally displaced material bulged up the overlying beds and caused the development of a shoal, or, in suitable circumstances, of an island. Naturally, in such a "bulge" the plastic, relatively fluid material is present in excessive amount, as compared with that in the more normally stratified lake deposits.

Further, methane and other gases produced by secular alteration of the vegetable contents of the muds, and stored in them to some extent, are liable to find an avenue of escape when the crest of a "bulge" becomes fractured through compression or tension. The escape of such imprisoned gas, especially under the dynamic conditions of flowage of large volumes of mud under pressure, is quite competent to account for the paroxysmal phases in the development of Mud Island which have been referred to by some observers.

That the whole of the gas supply was not exhausted by the paroxysmal stages is shown by the continued discharge of gas in small quantities.

It is to be noted, also, that the situation of Mud Island in relation to the sand spit is just what would be expected, and just what is encountered in similar occurrences elsewhere. The displaced mud cannot escape in all directions, because of the resistance offered by the mass of the relatively solid mainland; the whole of the force is spent *from* the shore and *towards* the open water, so that the "island" appears just offshore.

It is quite possible that, if sand bars were to accumulate in open water, the uplift would be more or less symmetrical, and therefore less intense in its local manifestations. For all that is known to the contrary many such readjustments of the lake bottom might take place without attracting attention, since there is no regular periodical resurvey of the lake floor in progress.

Analogous Phenomena in other Places.

Mud Lumps in the Mississippi Delta.

Since the phenomenon possesses more than academic interest, and since a most extraordinarily close parallel exists in the case of the "mud lumps" of the Mississippi Delta, investigated by Shaw (2, pp. 11-27), a somewhat detailed description of these structures may be given.

According to Shaw, "mud lumps," in the form of large swellings of blue mud, rise at intervals within a mile or two of each of the mouths of the Mississippi. In some instances the rise is sudden, though generally it extends over months or years. The lumps rise just offshore, and have a surface extent of an acre or more and a height of 5 to 10 feet. Other lumps do not reach the surface of the water, but form shoals. Usually the lumps attain a height of about 20 to 30 feet above the bottom in the vicinity. They rarely extend more than 8 feet or less than 2 feet above the water.

Their appearance and disappearance are very irregular. Many of them subside and some have disappeared in a night. Their formation is most active during flood periods, when aggradation is most extensive. Observations by pilots and sailors of the formation of the mud lumps are fairly consistent. Shaw doubts the authenticity of reports of roaring noises and flashes of light which have been made in one or two instances. The present writer finds no difficulty in accepting such reports, though the conclusions he draws therefrom are not those intended by the observers. It is probable that, occasionally, the formation of a "lump" is more paroxysmal than usual, because of somewhat abnormal gas accumulation. In such a case the roar would not be unexpected. It seems within the bounds of possibility, also, that during such a paroxysmal gas eruption, fragments of wet, shining mud might be thrown spinning into the air. Light, momentarily reflected from such wet, moving surfaces, might easily be mistaken by an unskilled observer for flashes of fire; particularly when the preconceived idea that the phenomenon as a whole is volcanic is taken into consideration.

Shaw states (2, pp. 24, 25), "The structure of the mud lumps appears to be comparable with that of bysmaliths. . . . A dark bluish grey clay of medium stickiness forms the central core. . . . Upon and around the core lies a series of faulted and folded strata of sand and silt which have been carried up from the sea bottom and deformed in the upheaval. The upper parts of the mud lumps bear numerous fissures and some normal faults. . . ."

"One of the most significant facts concerning the mud lumps is that they contain much more clay than has been found in other parts of the Delta deposits. . . . This strongly suggests that the mud lumps have been produced by the lateral flowage

of soft layers of clay, for no such thick layers of clay have been found elsewhere in the Delta."

The mud lumps nearly all give rise to mud springs which discharge salty sludge and gas. These springs are usually associated with fissures, though, in some instances, the fissures are well-nigh obliterated. The materials of the Mississippi Delta contain large amounts of both marsh gas and water. Gas escapes in many places, particularly in the vicinity of the mud lumps. This gas is found on analysis to consist of marsh gas, CH_4, mixed with nitrogen, oxygen and carbon dioxide. Such a composition indicates that the gas is not of deep-seated origin, but has developed within a few feet of the surface.

Shaw concludes, "The facts that the mud lumps are by far the thickest bodies of clay found in the Delta and that the clay is overlain and underlain by materials similar to those found elsewhere throughout the lower end of the Delta suggest that they are produced by the squeezing of the soft layers and the accumulation of clay from such layers in places where the pressure is less strong, and that the lumps are not upheaved by any such force as volcanism or by the pressure from the accumulation of salt, sulphur, or gas below the surface."

"The mud lumps appear to be the product of flow, because in no other places have such thick bodies of clay been formed, and the facts that they occur almost exclusively near the ends of the passes . . . where probably the principal part of the sediment is being deposited, and that they are most active during and after times of high (flood) water seems to be in accord with the hypothesis here presented."

"The flowage of semifluid clay has frequently been observed. It sometimes causes great difficulty in railway building, or gives rise to surprising changes in swamps."

Comments on the Views of Shaw.

Allowing for the vast difference in scale between the two cases, Shaw's description of the phenomena at the Mouth of the Mississippi, to which the author's attention has been drawn only very recently, applies almost word for word to the formation of "Mud Island" in Lake Victoria. The similar abnormalities of the two Deltas have been commented on above, and supply an additional reason for the correlation of the phenomena.

The activity of the Mississippi mud lumps "during and immediately after high water" is due, of course, to the fact that such periods mark the maximum imposition of sediment as loading on the bottom. Shaw quotes an estimate by an officer of the United States Corps of Engineers, in which it is stated that 2,500,000 cubic yards of material were deposited during the high water stage of the Mississippi from March to May, inclusive, 1913. This additional material produced an increased pressure

of 1,800,000 tons, or a mean additional pressure of 400 pounds per square foot. The maximum pressure was 825 pounds per square foot.

The author has brought forward reasons why a different cause may be sought to explain the time coincidence in the case of the formation of "Mud Island."

Various accounts of the formation of "Mud Island" suggest that there were one or more paroxysmal phases. It would appear from general considerations, and from the author's observations of the amount of vegetable debris present in the muds of the lake bottom, that there is a somewhat abnormally large amount of marsh gas generated in the locality.

Shaw advances many weighty reasons, too long for quotation *in extenso,* against the acceptance of the gas-origin theory. While these arguments are almost certainly valid in reference to the Mississippi mud lumps and the Victorian "Mud Island," it does not preclude the possibility of such action taking place under conditions favouring the generation and storage, under pressure, of unusually large amounts of gases derived from decomposing vegetation. Shaw himself quotes a case described by Potonié (3) where such an origin is suggested. The author has not had access to this work of Potonié's.

Analogies in Australia.

Instances of flowage of muds under the pressure of artificial embankments have been observed personally by the author.

In the construction of the railway embankments along the foreshores of Mullet Creek, Hawkesbury River, N.S.W., during 1887, phenomena very strikingly similar to the formation of Mud Island occurred. Mullet Creek is a deep, drowned river valley, completely filled with silty sediment. Small tributary gullies, similarly filled with silt, had to be crossed by means of embankments.

Much trouble and expense were caused by the foundering of these embankments, with the formation of mud islands of exactly the same type and in exactly the same relative position as that occupied by the Mud Island in Gippsland. It seems likely that most of the subsidences were gradual, but the author can remember that there were circumstantial accounts, at the time, of the complete disappearance of embankments overnight.

On another occasion, a railway embankment between Waratah and Sandgate, on the Hunter River Delta in N.S.W., was being enlarged, and a similar subsidence took place, rather suddenly, but not with paroxysmal violence. Swellings were thrown up in the swamps on both sides, and the forest trees were thrown markedly out of perpendicular.

The author has described a somewhat similar phenomenon in the Collie Coal Basin of Western Australia (4). In this case, the accumulation of thick masses of sand, which were being deposited to form the roof of the main seam in the area now being worked by the Westralian Colliery, caused a failure of the soft muds

forming the floor of the seam. The (still soft) coal was fractured and displaced, and large volumes of mud were injected through it into the roof sandstones. This formed a break in the continuity of the seam which had most serious consequences on the profitable working of the mine.

Objections to the Theory that the Formation of Mud Island is in any way connected genetically with the Tertiary Oil Sands of Lakes Entrance.

The reasons advanced for considering that both the mud lumps of the Mississippi and "Mud Island" in Lake Victoria are of purely superficial origin are so weighty that the author is unable to accept the alternative suggestion of connection, in the latter case, with underlying oil formations.

It seems necessary to recapitulate several facts which are regarded as conclusive evidence against such connection.

(1) The oil which has been encountered at Lakes Entrance occurs in glauconitic sandstone forming the basal beds of the Tertiary System in this area. These beds lie on an old, decomposed and eroded surface of granite and Older Palaeozoic strata; and the strong presumption is that the migration of the oil is along the unconformity.

(2) At Lakes Entrance, the base of the oil stratum is encountered at depths of 1275 feet in No. 2 Bore and 1404 feet in No. 3 Bore, Lakes Entrance, Parish of Colquhoun. This is in strict conformity with the surface indications of regional dip in the district, which amounts to only some 50 feet per mile in a general westerly direction.

(3) There is no authentic evidence of any disturbance of this gentle structure in the area under consideration. In absence of such evidence it is reasonable to assume that the official view of the Geological Survey, that the structure is a very uniform one, is correct.

(4) The basal Tertiary beds should be met with at a depth of about 2450 feet in the neighbourhood of the "Mud Island." That they will be found to contain small quantities of oil similar to those encountered at Lakes Entrance seems highly probable.

(5) The oil, so far discovered, is closely associated with artesian water. Up to the present it has not been found possible to effect a separation so that the oil can be extracted commercially. There is no evidence that the artesian water has been able to produce the violent paroxysmal outburst claimed to have been responsible for the formation of the mud island.

(6) Gas, in moderate quantities, is associated with the oil manifestations at Lakes Entrance. Its pressure is sufficient to keep it in evidence, in spite of the hydrostatic head of water rising to the surface. The pressure is, however, only just suffi-

cient for this, and there is no excess capable of producing violent eruptive effects in addition to balancing the water pressure.

(7) If the uplift at "Mud Island" marks the escape of imprisoned gas under high pressure from the oilsand along a fault plane, it is most extraordinary that the formation of the island should be its only manifestation, and that the appearance of the island should have been delayed until the present moment. If a leaky geological structure were present we should expect a line of similar manifestations in various stages from incipience to extinction. Examples of this kind are frequent in the case of the "mound springs" of Central Australia, which mark the outlets of the water from the Great Artesian Basin. The author claims to have made a suggestion which is adequate to explain, not only the phenomenon of formation of "Mud Island," but also the coincidence of its appearance at the present juncture.

(8) There is a high degree of probability of the formation of similar structures in the lakes in the future, in positions analogous with that occupied by mud island in relation to growing sand spits.

(9) The formation of somewhat similar mud islands and of "mud volcanoes" in direct and genetic association with existing oilfields is, of course, a well-known phenomenon. In such cases, however, the whole environment precludes the possibility of development by sedimentary overloading and favours that by oil and gas eruption. A case in point is the formation, recently, of a mud island immediately off the coast of Trinidad (5). While there are superficial points of resemblance between the phenomena in this case and in the formation of "Mud Island," no scientific reader could fail to distinguish the fundamental differences in every important particular.

Summary.

"Mud Island," which appeared in Lake Victoria about eight miles west of Paynesville, during 1928, owes its origin to an upheaval of the lake floor. This was produced by the lateral squeezing out of a sub-surface layer of plastic clay from beneath an area overloaded by the recent accumulation of sand, forming a spit extending out from the shore of Pelican Point on Sperm Whale Head.

The reason for the uniqueness of the phenomenon, and for its occurrence at this particular time, is believed to be that the effects of man's interference with the equilibrium between the processes of erosion and sedimentation, established over ages preceding white settlement of the area, are only just beginning to make themselves apparent.

Deforestation, stocking, agriculture, mining, road and railway construction, and other rapid disturbances of natural conditions, have combined to cause a comparatively rapid, and cumulatively

important, increase in the bulk of sedimentation in the Lakes, which has manifested itself in the bulging up of the lake floor locally.

Reasons are given for believing that the apparition has nothing whatever to do with the presence or absence of petroleum beneath the surface of this part of Victoria.

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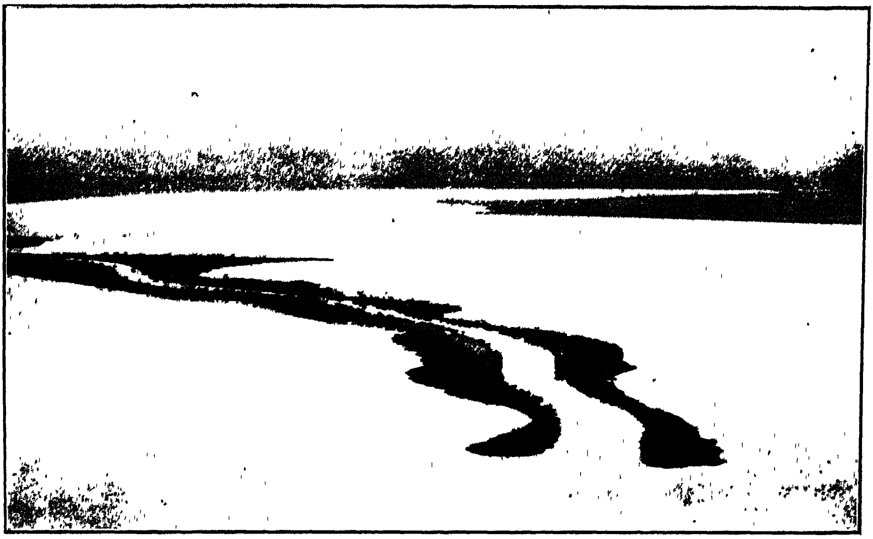
Explanation of Plate XXII.

Fig. 1.—Natural jetties of silt at mouth of Mitchell River, Gippsland Lakes.

Fig. 2.—Mud Island off Pelican Point, Sperm Whale Head, Gippsland Lakes, showing portion of shore of Pelican Point in left foreground.

Fig. 3.—Closer view of Mud Island, with launch anchored alongside.



F D. Bulmer photo

FIG. 1.

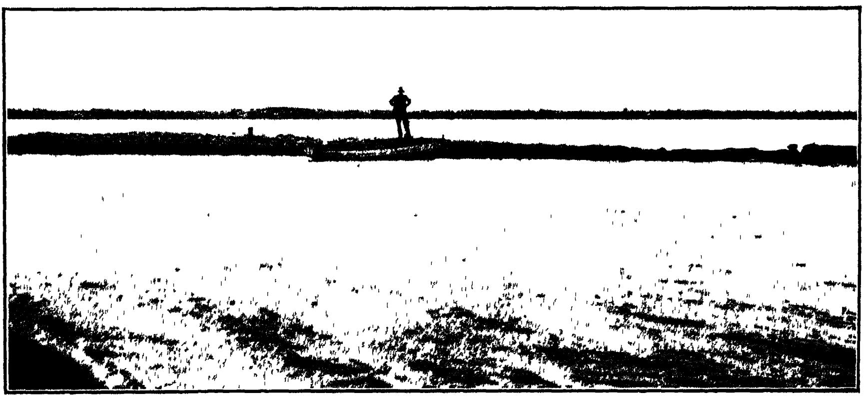


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FIG 2.

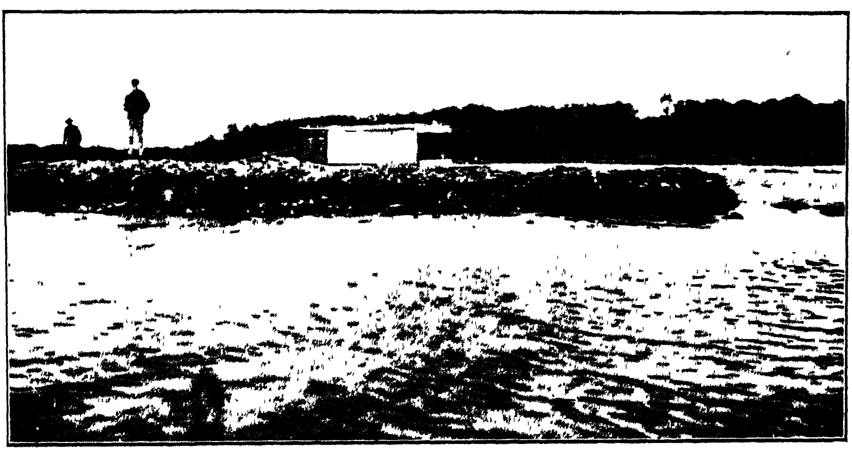

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FIG. 3.

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Abraham, W. S., Geological Survey Museum, Gisborne-street, East Melbourne, C.2. 1929

Albiston, H. E., M.V.Sc., Veterinary School, Parkville, N.2. 1925

Allen, J. M., M.A., 41 Nirvana-avenue, East Malvern, S.E.5. 1924

Allen, Miss N. C. B., B.Sc., University, Carlton, N.3 1918

Archer, Howard R., B.Sc., c/o J. M. Moffatt, Faulkner-street, Armidale, N.S.W. 1921

Ashton, H., "The Sun," Castlereagh-street, Sydney, N.S.W. 1911

Bage, Mrs. Edward, "Cranford," 7 Gellibrand-street, Kew, E.4. 1906

Bage, Miss F., M.Sc., Women's College, Kangaroo Point, Brisbane, Qld. 1906

Baker, F. H., 167 Hoddle-street, Richmond, E.1 1911

Barkley, H., Meteorological Bureau, cr. Victoria and Drummond-streets, Carlton, N.3. 1910

Barnard, R. J. A., M.A., University, Carlton, N.3 1926

Blake, A. S., 19 Rose-street, Ivanhoe, N.21 1929

Bordeaux, E. F. J., D.V.Sc., B. ès L., Mangalore-street, Flemington, W.2. 1913

Breidahl, H., M.Sc., M.B., B.S., 23 Chatsworth-avenue, North Brighton, S.5. 1911

Brodribb, N. K. S., Ordnance Factories, Maribyrnong, W.3. 1911

Buchanan, Gwynneth, D.Sc., University, Carlton, N.3 1921

Butler, S., 94 Carlisle-street, St. Kilda, S.2 1929

Carter, A. A. C., "Fairholm," Threadneedle-street, Balwyn, E.8. 1927

Chapman, W. D., M.C.E., "Hellas," Heidelberg-road, Clifton Hill, N.8. 1927

Chapple, Rev. E. H., The Manse, Warrigal-road, Oakleigh, S.E.12. 1919

Cheney, Miss G. M., B.Sc., 383 Glenferrie-road, Hawthorn, E.2. 1929

Cherry, R. O., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927

Clark, J., F.L.S., National Museum, Melbourne, C.1. 1929

Clinton, H. F., Produce Office, 605 Flinders-street, Melbourne, C.1.	1920
Collins, A. C., Public Works Department, Treasury Gardens, East Melbourne, C.2.	1928
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot-road, Hawthorn, E.2.	1919
Cookson, Miss I. C., B.Sc., 154 Power-street, Hawthorn, E.2.	1916
Coulson, A. L., M.Sc., D.I.C., F.G.S., "Finchley," King-street, Elsternwick, S.4.	1919
Cox, E. H., Literary Staff, "The Argus," Elizabeth-street, Melbourne, C.1.	1924
Crespin, Miss I., B.A., 67 Studley Park-road, Kew, E.4 ..	1919
Cudmore, Mrs. F. A., B.A., B.Sc., Dip.Ed., 12 Valley View-road, East Malvern, S.E.6.	1929
Dare, J. H., B.Sc., State School, Brunswick, N.10	1917
Deane, Cedric, "Cloyne," State-street, Malvern, S.E.4 ..	1923
Elford, F. G., B.Sc., 177 Albert-street, Sebastopol, via Ballarat, Vic.	1929
Feely, J. A., Observatory, South Yarra, S.E.1	1924
Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A.	1913
Ferguson, W. H., 37 Brinsley-road, E. Camberwell, E.6 ..	1894
Finney, J. M., "Armidale," Springvale-road, Forest Hill, Tunstall.	1925
Flecker, Dr. H., 71 Collins-street, Melbourne, C.1	1922
Gabriel, C. J., 293 Victoria-street, Abbotsford, N.9	1908
Grieve, Brian J., B.Sc., 194 Osborne-street, Williamstown, W.16.	1929
Hardy, A. D., F.L.S., Forests Department, Melbourne, C.2.	1903
Hauser, H. B., M.Sc., Geology School, University, Carlton, N.3.	1919
Hercus, E. O., D.Sc., F.Inst.P., University, Carlton, N.3	1923
Heslop, G. G., D.V.Sc., 7 Hudson-street, Caulfield, S.E.7.	1923
Hill, Gerald F., Council for Scientific and Industrial Research, Box 9, Canberra City, Canberra, F.C.T.	1924
Hills, E. S., M.Sc., Geology School, University, Carlton, N.3.	1928
Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1.	1913
Howitt, A. M., Department of Mines, Treasury Gardens, East Melbourne, C.2.	1910
Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7	1913
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1.	1927
Jona, J., Leon, M.D., M.S., D.Sc., "Hazelmere," 104 Wattle Tree-road, Malvern, S.E.4.	1914

Kannuluik, W. G., M.Sc., Natural Philosophy Dept., University, Carlton, N.3.	1927
Keartland, Miss B., M.Sc., Cramer-street, Preston, N.18	1919
Kubale, J. C., 167 Power-street, Hawthorn, E.2	1929
Lambert, C. A., Bank of N.S.W., Melbourne, C.1	1919
Leslie, J. R., 99 Toorak-road, South Yarra, S.E.1	1923
Llewelyn, Miss Sybil, M.A., M.Sc., St. Quentin, Broadway, Elwood, S.3.	1928
Luly, W. H., Department of Lands, Public Offices, Melbourne, C.2.	1896
Macdonald, B. E., Dairy Export Branch, Rialto, Collins-street, Melbourne, C.1.	1920
Mackenzie, G., 1 High-street, Prahran, S.1	1907
Maclean, C. W., 56 Cole-street, Elsternwick, S.4	1879
McLennan, Ethel, D.Sc., University, Carlton, N.3. ..	1915
Melhuish, T. D'A., M.Sc., Adelaide Chemical and Fertilizer Co., Currie-street, Adelaide, S.A.	1919
Mollison, Miss E., M.Sc., Royal-crescent, Camberwell, E.6.	1915
Moon, A. Ramsay, 32 Power-street, Hawthorn, E.2	1929
Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, East Melbourne, C.2.	1920
Morris, P. F., National Herbarium, South Yarra, S.E.1. ..	1922
Nelson, Miss E. A., M.A., M.Sc., University, Carlton, N.3	1924
Newman, B. W., Meteorological Bureau, cr. Victoria and Drummond-streets, Carlton, N.3.	1927
Nicholls, Miss Annie, B.Sc., 633 Inkerman-road, Caulfield, S.E.7.	1929
Oke, C., 56 Chaucer-street, St. Kilda, S.2	1922
Orr, D., B.Sc., 860 Mount Alexander-road, Essendon, W.5	1927
Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8	1927
Pern, Dr. Sydney, M.R.C.S., L.R.C.P., 16 Collins-street, Melbourne, C.1.	1920
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2.	1919
Petrie, A. H. K., M.Sc., Ph.D., University, Carlton, N.3 ..	1927
Pretty, R. B., M.Sc., Technical School, Warrnambool, Vic.	1922
Raff, Miss J. W., M.Sc., F.E.S., University, Carlton, N.3	1910
Rayment, Tarlton, Bath-street, Sandringham, S.8	1929
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11	1923
Rosenthal, Newman, H., B.A., B.Sc., 11 Wimbledon-ave., Elwood, S.3.	1921
Ross, Miss D. J., M.Sc., Merton Hall, Anderson-street, South Yarra, S.E.1.	1924

Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3. 1924

Sharman, P. J., M.Sc., "Glenalvie," 9 Daphne-street, Canterbury, E.7. 1916

Sherrard, Mrs. H. M., M.Sc., "Balnagowan," Bromley-ave., Cremorne, N.S.W. 1918

Shiels, D. O., M.Sc., Ph.D., Chemistry School, University, Carlton, N.3. 1927

Smith, J. A., 25 Collins-place, Melbourne, C.1 1905

Stickland, John, 433 Brunswick-street, Fitzroy, N.6. 1922

Sutton, C. S., M.B., B.S., 63 Toorak-road, South Camberwell, E.6. 1908

Thomas, R. G., B.Ag.Sc., c/o Dr. Thomas, Northam, W.A. 1922

Thompson, Mrs. G. R., 26 Fawkner-street, St. Kilda, S.2 1922

Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3. 1903

Treloar, H. M., Meteorological Offices, Melbourne, C 1 .. 1922

Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9 .. 1918

Turner, A. H., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927

Turner, A. W., M.V.Sc., Veterinary School, Parkville, N.2. 1925

Wilcock, E. L, B Sc., University High School, Carlton, N.3. 1925

Williamson, H. B., F.L.S., "The Grange," 231 Waverley-road, East Malvern, S.E.5. 1919

Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5. 1921

Wilson, Major H. W., O.B.E., M.C., C.de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7. 1923

Withers, R. B., 10 Nicholson-street, Coburg, N.13. 1926

LIST OF THE INSTITUTIONS AND LEARNED SOCIETIES THAT RECEIVE COPIES OF THE "TRANSACTIONS" AND "PROCEEDINGS" OF THE ROYAL SOCIETY OF VICTORIA.

ARGENTINA.

Academia Nacional de Ciencias Exactas - - - Cordoba
Facultat de Ciensias Fisicomatematicas, Comision de publicasiones La Plata
Museo de la Plata - - - - - - - - Buenos Ayres
Sociedad Cientifica Argentina - - - - Buenos Ayres

AUSTRALIAN COMMONWEALTH.

Australian Forestry School - . - - - - - Canberra
Central Weather Bureau - - - - - - - Melbourne
Commonwealth Bureau of Census and Statistics - Canberra
Council for Scientific and Industrial Research - Melbourne
Federal Parliamentary Library - - - - - - Canberra

AUSTRIA.

Akademie der Wissenschaften - - - - - - - Vienna
Geographische Gesellschaft in Wien - - - - - - Vienna
Geologische Bundesanstalt - - - - - - - - Vienna
Naturhistorisches Museum in Wien - - - - Vienna
Zoologisch-Botanische Gesellschaft in Wien - - - Vienna

BELGIUM.

Académie Royale des Sciences de Belgique - - Bruxelles
Société Belge de Géologie - - - - - - - - Bruxelles
Société Geologique de Belgique - - - - - - Liege
Société Royale Zoologique Malacologique de Belgique Bruxelles

BRAZIL.

Commissao Geographica e Geologica do Estado de S. Paulo S. Paulo
Museu Paulista - - - - - - - - - - - - - S. Paulo
Sociedade Scientifica - - - - - - - - - - S. Paulo

CANADA.

Geological Survey of Canada - - - - - - - Ottawa
International Institute, Dept. of Agriculture, West Block Ottawa
McGill University - - - - - - - - - - Montreal
Nova Scotian Institute of Science - - - - - - Halifax
Royal Canadian Institute - - - - - - - - Toronto
Royal Society of Canada - - - - - - - Montreal

CHINA.

Manchuria Research Society - - - - Harbin, Manchuria

CZECHO-SLOVAKIA.

Czechoslovak Botanical Society - - - - - - Prague
Naturwiss. Zeitschrift "Lotos" - - - - - - - Prague
Observatoire National de la Republique Tchécoslovaque Prague

ENGLAND.

Agent-General of Victoria - - - - - - - London
Annual Tables of Constants and Numerical Data
Sandford House, Aylburton
Balfour Library - - - - - - - - - - Cambridge
Bodleian Library - - - - - - - - - - - Oxford
British Museum - - - - - - - - - - - London
Conchological Society of Great Britain and Ireland Manchester
Dove Marine Laboratory - - Cullercoats, Northumberland
Eugenics Education Society - - - - - - - London
Fisheries Dept., Ministry of Agriculture and Fisheries London
Geological Society - - - - - - - - - - London
Geologists' Association - - - - - - - - London
Imperial Bureau of Entomology - - - - - London
Imperial College of Science and Technology - - London
Institute of Mining and Mechanical Engineers - Newcastle
Linnaean Society - - - - - - - - - - - London
Literary and Philosophical Society - - - - Manchester
Liverpool Biological Society - - - - - - Liverpool
Liverpool School of Tropical Medicine - - - Liverpool
Manchester Museum - - - - - - - - - Manchester
Marine Biological Laboratory - - - - - - Plymouth
National Physical Laboratory - - - - - - Middlesex
Natural History Museum - - - - - - - - London
"Nature" - - - - - - - - - - - - London
Patents Office - - - - - - - - - - London
Philosophical Society - - - - - - - - Cambridge
Physical Society - - - - - - - - - - London
Reference Library - - - - - - - - - - Liverpool
Royal Anthropological Institute of Great Britain and Ireland
London
Royal Colonial Institute - - - - - - - - London
Royal Botanic Gardens - - - - - - - - - Kew
Royal Geographical Society - - - - - - - London
Royal Microscopical Society - - - - - - - London
Royal Society - - - - - - - - - - - London
Science Abstracts - - - - - - - - - - London
Science Museum, Sth. Kensington - - - - - London
University Library - - - - - - - - - Cambridge
Zoological Society of London - - - - - - London

DENMARK.

Dansk Naturhistorisk Forening, Zoo. Mais. - - Copenhagen
Kon. Danske Videnskabernes Selskab - - - Copenhagen
Zoological Museum - - - - - - - - - Copenhagen

FINLAND.

Abo Akademi - - - - - - - - - - Abo, Finland
Commission Géologique de Finlande - - - - Helsingfors
Societas Scientiarum Fennica - - - - - Helsingfors
Societas pro Fauna et Flora, Fennica - - - Hensingfors

FRANCE.

Académie des Sciences, Belles Lettres et Arts - - Lyons
Faculté des Sciences - - - - - - - - - Marseilles
Laboratoire de Zoologie et de Physiologie Maritimes
Concarneau
Muséum National d'Histoire Naturelle - - - - Paris
Société des Sciences Naturelles de l'Ouest de la France Nantes
Société Geologique du Nord - - - - - - - - Lille
Société Nationale des Sciences Naturelles et Mathématiques
de Cherbourg - - - - - - - - - - Cherbourg
Société Zoologique de France - - - - - - - Paris
Station Zoologique de Cette - - - - - Cette (Herault)
Université de Rennes - - - - - - - - - Rennes

GERMANY.

Bayerische Akademie der Wissenschaften - - - Munich
Biologische Anstalt auf Helgoland - - - - Heligoland
Deutsche Geologische Gesellschaft - - - - - Berlin
Gesellschaft der Wissenschaften - - - - - Gottingen
Medicinisch Naturwissenschaftliche Gesellschaft zu Jena Jena
Museum für Natur-und Heimatkunde und der Natur-
wissenschaftliche Verein - - - - - Magdeburg
Naturhistorische Gesellschaft zu Nürnberg - - Nüremberg
Naturhistorisch-Medicinischer Verein - - - Heidelberg
Naturhistorischer Verein der preussischen Rheinlande und
Westfalens - - - - - - - - - - - Bonn
Naturwissenschaftlicher Verein für Schleswig-Holstein - Kiel
Naturwissenschaftlicher Verein zu Bremen - - Bremen
Oberhessische Gesellschaft für Natur u. Heilkunde zu Giessen
Giessen
Physikalisch-medicinische Gesellschaft zu Würzburg Würzburg
Preussische Akademie der Wissenschaften - - - Berlin
Provinzial Museum - - - - - - - - - Hannover
Sachs. Gesellschaft der Wissenschaften - - - - Leipzig
Schlesische Gesellschaft für Vaterländische Cultur - Breslau

Senckenbergische Naturforschende Gesellschaft - Frankfurt on M.
Zoologisches Museum der Universität - - - - - Berlin
Zoologische Staatsinstitut u. Zoologische Museum - Hamburg
Wanderversammlungen Deutscher Entomologen - - Berlin

HAWAIIAN ISLANDS.

Bernice Pauahai Bishop Museum - - - - - - Honolulu

HOLLAND.

Kon. Akademie van wetenschappente - - - Amsterdam
Musée Teyler - - - - - - - - - - - - Haarlem
Nederlandsche Botanische Vereeniging - - - Amsterdam
Provincial Utrechtsch Genootschap van Kunsten en Wetenschappen - - - - - - - - - - Utrecht
Rijks Geologisch-Mineralogisch Museum te Leiden - Leyden
Rijks Herbarium - - - - - - - - - - - - - Leyden

INDIA.

Agricultural Research Institute - - - - - - - Pusa
Asiatic Society of Bengal - - - - - - - - Bengal
Colombo Museum - - - - - - - - - - - Columbo
Geological Survey of India - - - - - - - - Calcutta
Indian Chemical Society - - - - - - - - - Calcutta
Indian Museum - - - - - - - - - - - - Calcutta
Royal Asiatic Society of Great Britain and Ireland, Ceylon Branch - - - - - - - - - - - Columbo

JAVA.

Bataviaasch Genootschap van Kunsten en Wetenschappen - Batavia
Dept. of Landbouw, Nijverheid en Handel - - Buitenzorg
Kon. Magnetisch Meteorologisch Observatorium - Batavia

JAPAN.

College of Agriculture, Kyoto Imperial University - Kyoto
Imperial Fisheries' Institute - - - - - - - - Tokyo
Imperial University - - - - - - - - - - - Tokyo
Kyoto Imperial University - - - - - - - - Kyoto
Noso Experimental Station of Forestry - Taihoku, Formosa
Ohara Instituts, fur landwirtschaftliche Forschungen, Kuraschiki, Provinz - - - - - - - - - Okayama
Saito Ho-on Kai - - - - - - - - - - - Sendai
Tohoku Imperial University - - - - - - - Sendai

IRELAND.

Belfast Natural History and Philosophical Society - Belfast
Royal Dublin Society - - - - - - - - - - Dublin
Royal Irish Academy - - - - - - - - - - Dublin
Trinity College Library - - - - - - - - - Dublin

ITALY.

Istituto geografico de Agostini - - - - - - - Novara
Laboratorio di Entomologia, R. Instituto Superiore Agrario di Bologna - - - - - - - - - - - - Bologna
Laboratorio di Zoologia generale e agraria del R. Instituto Superiore Agrario di Portici - - - - - - Portici
"Malpighia," R. Instituto Botanico dell'Università di Bologna Bologna
Ministero dei Lavori Pubblici - - - - - - - - Rome
Musei di Zoologia ed Anatomia Comp., R. Università Turin
R. Accademia Nazionale dei Lincei - - - - - - Rome
R. Accademia delle Scienze dell'Instituto di Bologna Bologna
R. Accademia Lucchese di Scienze, Lettere ed Arti - Lucca
R. Società Geografica Italiana - - - - - - - - Rome
Regia Accademia di Scienze, Lettere ed Arti - - Modena
Società Geologica Italiana - - - - - - - - - Rome
Società Toscanadi Scienze Naturali . - - - - - - Pisa
Stazione Zoologica di Napoli - - - - - - - - Naples

MEXICO.

Instituto Geologico de Mexico - - - - - Mexico D.F.
Ministerio de Fomento - - - - - - - - Mexico D.F.
Puseo Nacional - - - - - - - - - - - Mexico D.F.
Sociedad Científica "Antonio Alzate" - - - Mexico D.F.

NEW SOUTH WALES.

Australian Museum - - - - - - - - - - Sydney
Botanic Gardens - - - - - - - - - - - - - Sydney
Department of Agriculture - - - - - - - - Sydney
Department of Mines - - - - - - - - - - - Sydney
Linnaean Society of New South Wales - - - - Sydney
Public Library - - - - - - - - - - - - - - Sydney
Royal Society of New South Wales - - - - - Sydney
Technological Museum - - - - - - - - - - Sydney
University Library - - - - - - - - - - - - Sydney

NEW ZEALAND.

Auckland Institute and Museum - - - - - - Auckland
Dominion Museum - - - - - - - - - - - Wellington
Geological Survey - - - - - - - - - - - Wellington

Museum - - - - - - - - - - - - - - Christchurch
New Zealand Institute - - - - - - - - - Wellington
Otago Institute - - - - - - - - - - - - Dunedin

NORWAY.

Archiv for Mathematik og Naturvidenskab - - - Oslo
Bergens Museum - - - - - - - - - - - Bergen
Kongl. Norske Videnskabers-Selskabs - - - Trondjem
Norske Videnskaps-Akademi i Oslo - - - - - - Oslo
Nyt Magazin for Naturvidenskaberne - - - - - Oslo
Université Royale de Norvege - - - - - - - - Oslo

PERU.

Cuerpo de Ingenieros de Minas del Peru - - - Lima

PHILIPPINE ISLANDS.

College of Agriculture, University of Philippines - Laguna

POLAND.

Société polonaise des Naturalistes "Kopernik" - - Lwow

PORTUGAL.

Academia de Sciencias de Portugal - - - - Lisbon
Instituto botanica da Universidade de Coimbra - - Coimbra

QUEENSLAND.

Australian Institute of Tropical Medicine - - Townsville
Geological Survey Office - - - - - - - - - Brisbane
Queensland Museum - - - - - - - - - - - Brisbane
Royal Geographical Society - - - - - - - - Brisbane
Royal Society of Queensland - - - - - - - Brisbane
University of Queensland - - - - - - - - - Brisbane

RHODESIA.

Rhodesia Museum - - - - - - - - - - - Buluwayo

ROUMANIA.

Facultatea de Stünte de pe langa Universitatea din Cernauti
Cernauti
Institut Météorologique de Roumanie - - - Bucharest

SCOTLAND.

Botanical Society of Edinburgh - - - - - - Edinburgh
Royal Philosophical Society of Glasgow - - - Glasgow
Royal Physical Society for Promotion of Zoology and other Branches of Natural History - - - - Edinburgh
Royal Scottish Geographical Society - - - - Edinburgh
Royal Society - - - - - - - - - Edinburgh

SOUTH AUSTRALIA.

Department of Chemistry - - - - - - - Adelaide
Department of Mines - - - - - - - - Adelaide
Public Library and Museum - - - - - - Adelaide
Royal Geographical Society - - - - - - Adelaide
Royal Society of South Australia - - - - - Adelaide
University - - - - - - - - - - - Adelaide

SPAIN.

Institut d'Estudis, Catalans, Palau de la Diputacio - Barcelona
Junta para Ampliacion de Estudios e Investigaciones Cientificas - - - - - - - - - - Madrid
Real Academiá de Ciencias exactas, físicas y naturales Madrid
Sociedad Espanola de Antropologia, Etnografia y Prehistoria Madrid

SWEDEN.

Centralanstaltens Entomologiska Avdelning - - Stockholm
Entomologiska Föreningen i Stockholm - - - Stockholm
Kungl. Universitets - - - - - - - - - - Upsala
Kungl. Svenska Vetenskaps-Akademi - - - Stockholm
Sveriges Geologiska Undersökning - - - - Stockholm
Zootomisches Institut der Universitet - - - Stockholm

SWITZERLAND.

Geographische Gesellschaft von Bern - - - - Berne
Naturforschende Gesellschaft in Basel - - - - Basel
Naturforschende Gesellschaft in Zürich - - - - Zürich
Schweizerische Naturforschende Gesellschaft - - - Berne
Société de Physique et d'Histoire Naturelle - - Geneva

TASMANIA.

Geological Survey, Mines Department - - - - Hobart
Royal Society of Tasmania - - - - - - - Hobart
University of Tasmania - - - - - - - - Hobart

UNION OF SOUTH AFRICA.

Albany Museum - - - - - - - - - - Grahamstown
Durban Museum - - - - - - - - - - Durban

Geological Survey, Dept. of Mines & Industries - Pretoria
Geological Society of South Africa - - - Johannesburg
Nasionale Museum - - - - - - - - Bloemfontein
Natal Museum - - - - - - - - Pietermaritzburg
Royal Society of South Africa - - - - - - Capetown
S. African Assoc. for the Advancement of Science Capetown
South African Museum - - - - - - - - Capetown

UNITED STATES OF AMERICA.

Academy of Natural Sciences - - - Philadelphia Pa.
Academy of Natural Sciences - - - Philadelphia, Pa.
Academy of Sciences of St. Louis - - - St. Louis, Mo.
American Institute of Mining and Metallurgical Engineers New York
American Microscopical Society - - - - Urbana, Ill.
American Museum of Natural History - - - New York
American Academy of Arts and Sciences - - Boston, Mass.
American Geographical Society of New York - New York
American Philosophical Society - - - - Philadelphia
Arnold Arboretum, Harvard College - - Cambridge, Mass.
Biological Survey of the Mt. Desert Region Corfield Bar Harbor, Maine
Boston Society of Natural History - - - Boston, Mass.
Bureau of Ethnology, Smithsonian Institute - Washington, D.C.
Bureau of Standards, Dept. of Commerce - Washington, D.C.
California Academy of Sciences - - San Francisco, Cal.
Connecticut Academy of Arts and Sciences - New Haven, Conn.
Cooper Union for the Advancement of Sciences and Art New York
Davenport Academy of Natural Sciences - Davenport, Iowa
Department of Agriculture - - - - Washington, D.C.
Field Museum of Natural History - - - - - Chicago
Franklin Institute of the State of Pennsylvania Philadelphia, Pa.
Geographical Society of Philadelphia - Philadelphia, Pa.
Geological Department of Florida - - Tallahassee, Florida
Geological Society of America - - - - Cleveland, Ohio
Geological Survey - - - - - - Des Moines, Iowa
Graduate School of Tropical Agriculture and Citrus Experimental Station - - - - - - California
Iowa Academy of Sciences - - - - Des Moines, Iowa
Iowa State University - - - - - - Iowa City, Iowa
Johns Hopkins University - - - - Baltimore, Maryland
Lloyd Museum and Library - - - - Cincinnati, Ohio
Marine Biological Laboratory - - - Wood's Hole, Mass.
Missouri Botanical Garden - - - - - St. Louis, Mo.
Museum of Brooklyn Institute of Arts and Sciences Brooklyn, N.Y.
Museum of Comparative Zoology - - - Cambridge, Mass.

National Academy of Science, Smithsonian Institute, Washington, D.C.
New York State Library - - - - - - Albany, N.Y.
N.Y. State College of Agriculture - - - Ithaca, N.Y.
Ohio Academy of Sciences - - - - - - Columbus, Ohio
Smithsonian Institution - - - - - - Washington, D.C.
State Geological Survey - - - Grand Forks, N. Dakota
State Laboratory of Natural History - - Urbana, Illinois
San Diego Society of Natural History - San Diego, Cal.
Stanford University - - - - - - - - San Francisco
Texas Academy of Sciences - - - - - - Austin, Tex.
United States Dept. of Agric. State Relations Washington, D.C.
United States Coast and Geodetic Survey - Washington, D.C.
United States Geological Survey - - - Washington, D.C.
University of California - - - - - - - Berkeley, Cal.
University of Chicago - - - - - - - - - Chicago
University of Kansas - - - - - - - Lawrence, Kan.
University of Illinois - - - - - - - - Urbana, Ill.
University of Michigan - - - - Ann Harbor, Michigan
University of Minnesota - - - - Minneapolis, Minnesota
University of Missouri - - - - - - - Columbo, Mo.
Washington University - - - - - - - St. Louis, Mo.
Wisconsin Academy of Sciences, Arts, and Letters Madison, Wis.

URUGUAY.

Museo de Historia Natural - - - - - Monte Video

U.S.S.R.

Institut des Recherches Biologiques à l'Université de Perm Perm
Jardin Botanique Principal de l'U.S.S.R. - - - Leningrad
Jardin Botanique de Kieff - - - - - - - - - Kieff
L'Académie des Sciences de l'U.S.S.R. - - - Leningrad
Latvia, University, Botanical Gardens - - - - Riga
Société des Naturalistes Kieff - - - - - - - Kieff
Société Botanique de L'Ukraine - - - - - - - Kieff
Société des Naturalistes - - - - - - - - Odessa
Société des Amis des Sciences Naturelles d'anthropologie et d'ethnographie - - - - - - - - - Moscow
Société des Naturalistes de Leningrad - - - Leningrad
U.S.S.R. Society of Cultural Relations - - - - Moscow

VICTORIA.

"Age" - - - - - - - - - - - - - - Melbourne
"Argus" - - - - - - - - - - - - - Melbourne
Astronomical Observatory - - - - - - - South Yarra
Australasian Institute of Mining and Metallurgy - Melbourne
Chemical World of Australia, Yorkshire House - Melbourne

Chief Secretary's Office - - - - - - -	Melbourne
Department of Agriculture, Science Branch - -	Melbourne
Department of Mines and Water Supply - - -	Melbourne
Field Naturalists' Club of Victoria - - - -	Melbourne
Free Library - - - - - - - - -	Geelong
"Herald" - - - - - - - - - -	Melbourne
National Herbarium - - - - - - -	Melbourne
National Museum - - - - - - - -	Melbourne
Parliamentary Library - - - - - - -	Melbourne
Pharmaceutical Society of Australasia - - -	Melbourne
Public Library - - - - - - - - -	Melbourne
School of Mines - - - - - - - - -	Ballarat
School of Mines - - - - - - - - -	Bendigo
Society of Chemical Industry - - - - - -	Melbourne
University Library - - - - - - - -	Melbourne
Victorian Institute of Engineers - - - - -	Melbourne

WEST AUSTRALIA.

Geological Survey Office - - - - - - - -	Perth
Royal Society of Western Australia - - - - -	Perth
University Library - - - - - - - - -	Perth
Western Australian Museum and Art Gallery - -	Perth

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The names of new genera and species are printed in italics.

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